# Exhibit 2

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# In re Flint Water Cases,
# No. 16-cv-1044

# Rebuttal Report of Dr. Larry L. Russell

March 29, 2021

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# 1 Executive Summary

This report addresses expert reports and rebuttal reports provided by the LAN and Veolia experts William Bellamy, David Duquette, Graham Gagnon, Brian Ramaley, and Desmond Lawler/Lynn Katz. A general overview of my response is provided herein. A detailed analysis and rebuttal to each of these reports is provided in the corresponding sections of the Appendix. The Appendix also contains an analysis of two research papers from Dr. Marc Edwards's group, as these papers were relied upon by many of the defense experts, and a further appendix addressing certain technical details.

My June 30, 2020 Expert Report (my 2020 report henceforth) provided eleven opinions related to LAN, Veolia, and the Flint Water Crisis. Those opinions addressed four primary aspects of the Flint Water Crisis.

i) Applicable engineering standard of care
ii) Breach of the engineering standard of care
iii) Evidence of harm to the plumbing systems and water quality throughout Flint
iv) Evaluation of the conditions that qualify the residences and businesses of Flint to be characterized as a Class

The Defense Experts ultimately fail to rebut the opinions presented in my 2020 report and my subsequent deposition. They fail to establish that LAN and Veolia met the standard of care related to corrosion in Flint. They fail to successfully rebut or contest the common issues, which were experienced throughout the City of Flint and which are shared by the members of the Class.

One of the primary roles of my report was to memorialize and evaluate the common issues which tie together the residents of the Flint Water Cases as members of a class. The authors of these rebuttal reports attempt to obscure the issues, and ignore what actually happened in Flint, especially with respect to LAN's and Veolia's failures to meet their standard of care obligations to the City of Flint and its residents. Even more relevantly, the LAN and Veolia experts fail to contest the class certification issues and opinions that tie together the residents of Flint, who were all impacted similarly by the Flint Water Crisis.

The Defendants' experts focus most of their analysis on disputing the applicable standard of care and opining on whether LAN and Veolia satisfied it. While I disagree with their analysis and the assertion by those experts that LAN and Veolia met the Standard of Care, the opinions presented by those experts serve to confirm the class-wide nature of the water issues in Flint. As a prime example, the defense experts do not dispute that the issues of what standard of care applies to the work of the professional engineering firms and of whether the engineering firms satisfied that standard are common throughout the proposed class. The work presented by these experts also never contests that every property in Flint was exposed to the same corrosive water during the Flint Water Crisis. Their work also neither successfully rebuts that damage was caused to the plumbing systems during the Flint Water Crisis, nor that the damage needs to be repaired with pipe and fixture replacement in the Flint residences and businesses.

The authors of these reports simply ignore the extensive body of evidence that opposes their positions. The authors cherry-pick from the available information, and present their facts in an often misleading or inaccurate manner. They similarly attempt to generate a laundry list of issues regarding the opinions and supporting information presented in my 2020 report and subsequent depositions. However, the issues raised are mainly attempts to distract from the actual events of the Flint Water Crisis and, particularly, the

engineering firms' failure to take steps that could have averted or substantially mitigated the crisis. These issues are detailed and rebutted in the following sections.

LAN and Veolia were each in a role through which they could have provided sound engineering advice that would have either avoided the Flint Water Crisis (LAN) or averted a substantial portion of the harm resulting from the Flint Water Crisis (LAN and Veolia). As shown by LAN's and Veolia's experts, the engineering required to prevent or avert the damage of the Flint Water Crisis simply wasn't provided to the City by its consultants, LAN and Veolia.

The engineering teams at LAN and Veolia had engineering ethical obligations to the City of Flint and the residents of Flint, as these engineers were the last line of defense between the Flint Water Crisis and the people. As the knowledgeable professionals on-site, they needed to provide the expertise and judgment that could have ultimately allowed for the production of safe and drinkable water. LAN and Veolia failed to meet their professional responsibilities on a variety of fronts, including by failing to assess the corrosive nature of Flint River Water, failing to provide appropriate recommendations for corrosion control, and failing to protect both human health and property throughout Flint. As is clearly evident from the results of the Flint Water Crisis, both LAN and Veolia failed to meet these obligations, and they failed to meet the obligatory standard of care.

# 2 Failure to Rebut Russell 2020 Expert Report Opinions

My 2020 expert report presented eleven opinions on the actions of LAN and Veolia in Flint, and the common class-wide impacts of the Flint Water Crisis. The defense experts fail to effectively rebut these eleven opinions, and the defense experts fail to rebut the common issues that were experienced by the members of the Class.[1]

This section presents the eleven opinions from my 2020 report, followed by an analysis of how the Defense experts fail to address or rebut each opinion. While touched on briefly here, each of the expert reports is analyzed in depth in their respective Appendices, and in additional sections of this report and accompanying appendix. In some cases, the quoted opinions below are condensed and/or edited from those presented in my 2020 report.

**Russell Opinion 2020-1: The water quality crisis in Flint should have been directly addressed through the institution of proven conventional water treatment technology and practice. There were six root technical issues that caused the water crisis resulting from the use of the Flint River for drinking water between April 25th 2014 and October 16th 2015.**

This opinion argues that the Flint Water Crisis could have been prevented with the application of traditional water treatment technologies and practices. The LAN and Veolia experts fail to effectively rebut this opinion. The LAN experts, Mr. Ramaley and Professors Lawler and Katz, do not rebut that the Flint Water Crisis could have been prevented by conventional water treatment technology and practices. The Veolia experts, Professors Duquette, Bellamy and Gagnon, do not rebut that the Flint Water Crisis could have been addressed by conventional water treatment technology and practice.

This opinion further includes six technical issues and practices that could have prevented the Flint Water Crisis. The six subsections of this opinion are summarized below. Any one of these practices would have gone a long way toward ameliorating the Flint Water Crisis. An overview of the Defense experts' responses (or lack thereof) follows.

1. Identify the corrosive nature of the water and implement corrosion control optimization
2. Evaluate blending of DWSD and Flint River Water
3. Switch back fully to DWSD water
4. Insist on the immediate installation of corrosion control
5. Cease use of ferric chloride in the treatment system
6. Understand the role of the water quality and treatment method on bacterial growth and microbially induced corrosion (MIC) in the plumbing systems

LAN provided technical expertise supporting the switch to treating and distributing the Flint River water. Switching water sources is one of the most challenging activities for water quality professionals. The switch must be approached with a sound and comprehensive engineering approach or substantial water quality problems will be encountered.

[1] I understand that a further deposition of Warren Green, acting as the corporate representative for Leo A. Daly and Lockwood, Andrews, and Newnan (LAD/LAN) was recently completed. I anticipate that I will review that transcript once a final transcript is available, and reserve the right to supplement my opinions to address Mr. Green's further testimony, which I understand did not identify any documented basis for disputing my opinions regarding the conduct of LAD/LAN.

The LAN experts Professors Lawler and Katz focus on the treatment methods recommended by LAN and the knowledge of corrosion indices available to engineers when LAN was working in Flint. They argue that LAN's proposed treatment method could have provided adequate corrosion control, and that the state of corrosion science was such in 2013 that LAN couldn't have known the Flint River water was corrosive. While I disagree with these positions, they do not fundamentally rebut the opinion that traditional water treatment methods and practices could have prevented the Flint Water Crisis, either by implementing adequate corrosion control treatment, or by returning to the DWSD source. See the Lawler and Katz Appendix for additional analysis.

The LAN expert Mr. Ramaley argues that LAN played no role in advising on water quality in Flint and that the LAN did in fact recommend adequate corrosion control including orthophosphate. He further argues that LAN had no standing to recommend a return to DWSD water (blended or 100 percent). While I disagree with these fundamentally unsupported positions, Mr. Ramaley is in effect supporting the position that traditional treatment methods and practices could have averted the Flint Water Crisis. See the Ramaley Appendix for additional analysis.

Veolia had the opportunity to address the corrosion issues in Flint when they were hired in 2015. At the time they began, signs of corrosion were presenting themselves throughout the water system.

The Veolia expert Professor Bellamy argues at length about the appropriateness of Veolia's treatment recommendations as they relate to disinfection byproducts, and about how various aspects of the water system, and the return to DWSD, were out of Veolia's contract scope. With regards to corrosion issues, Bellamy argues about what Veolia both did and didn't know of the issues at the time of their engagement, and that the treatment system modifications recommended by Veolia would have "…lowered corrosion rates." While I disagree with many of Professor Bellamy's positions, he does not contest that traditional water treatment methods and practices could have averted the Flint Water Crisis once Veolia was involved. See the Bellamy Appendix for additional analysis.

The Veolia expert Gagnon does not address this opinion.

The Veolia expert Professor Duquette generally does not address this opinion, with the exception of the topic of ferric chloride. He argues, without evidence or supporting documents, that ferric chloride additions would have "no effect" on corrosion. This position is not supported by the available research and publications on the topic, and does not present a technically sound or supported opposition to this opinion or the position stated in my 2020 report regarding the need to cease the use of ferric chloride. Professor Duquette does not oppose that conventional treatment technology and practices could have averted the Flint Water Crisis. See the Duquette Appendix for additional analysis.

**Russell Opinion 2020-2: Veolia practiced below the Standard of Care for engineers and water treatment operators.**

Of the Veolia experts, only Professor Bellamy takes a position regarding standard of care. He claims that "VNA met the standard-of-care and professionalism expected of consulting engineers while engaged by the City of Flint." He supports this position based on four areas of Veolia's role:

1) delivery of identified service;

2) environmental, safety, and health;

3) notify, advise, and recommend additional work; and

4) meeting the needs of the client.

These four categories do not inherently define the standard of care, and in some cases do not even apply. As is described at length in the Bellamy Appendix, and my 2020 report, Veolia failed to meet their standard of care. Veolia violated the standard of care in multiple ways regarding their work in Flint. For instance, Veolia failed to warn the City that the presence of highly corrosive water in the distribution system posed an immediate threat to human health and property. Veolia failed to conduct rudimentary corrosion evaluation calculations, including CSMR, and Veolia failed to recommend a return to DWSD water ([redacted] and this approach was ultimately the solution to the Flint Water Crisis in October 2015). Veolia failed to adequately recommend the use of a corrosion inhibitor, or to optimize the corrosion control treatment at Flint. Professor Bellamy argues that Veolia did recommend corrosion control and did determine that the water in Flint was likely corrosive and subject to issues with lead. As is documented thoroughly in the Bellamy Appendix, Veolia did not make adequate recommendations for corrosion control and, in fact, failed to address corrosion control as part of their work. Professor Bellamy accordingly fails to effectively rebut the opinion that Veolia did not meet the standard of care, as discussed in the Bellamy Appendix.

**Russell Opinion 2020-3: LAN practiced below the standard of care for professional engineers and water treatment operators by failing to provide advice that was consistent with proven engineering water treatment practice.**

The LAN experts, Professors Lawler and Katz, state that they were tasked with addressing standard of care, but fail to present a position on standard of care in their expert report. The Professors present arguments that LAN's treatment recommendations, including lime softening, could have met EPA guidance on corrosion control, at the time. They argue that corrosion science was not sufficient in 2013 for LAN to evaluate the corrosivity of the water; however, they fail to acknowledge that the City of Detroit's (DWSD) consultants recognized in 1992 that it was essential to add orthophosphate to control corrosion. In direct opposition to their position on softening as corrosion control, Professors Lawler and Katz note that water "…softening is not generally considered a primary means of corrosion control…" In my opinion, implementing lime softening as the primary corrosion control method was below the standard of care. As presented in my 2020 report, Appendix 1, and the Lawler and Katz Appendix, I do not agree that LAN met the standard of care.

The LAN expert Mr. Ramaley addressed a variety of topics related to LAN and their standard of care obligations. Regarding standard of care, Mr. Ramaley makes statements such as, *"…I conclude that LAN met their standard of care in public health to a degree that no one else involved at the City, MDEQ, and perhaps at EPA, did."* The actions of MDEQ, the City of Flint, and the EPA do not establish that LAN

met the standard of care. Mr. Ramaley's provides a section titled *STATEMENT OF OPINIONS AND CONCLUSIONS*, in which he claims that LAN met the standard care due to the following four areas:

1) The "Michigan Model Jury Instructions" and the following three opinions;
2) No "Water Advisor" role was ever described, assigned or allowed to be filled by LAN;
3) LAN's contractual scope began broadly defined but quickly narrowed; and
4) LAN violated no standards of ethics or contractual obligations in the performance of LAN's work related to the FWTP, especially as it related to corrosion control and public health.

LAN failed to meet the standard of care in multiple ways regarding their work in Flint. LAN was retained again by the City of Flint in June of 2013. Their contract clearly included aspects that define the role of the *water advisor* including [redacted]):

[redacted]

LAN's contract clearly delineates its role as the City of Flint's general water advisor. The task of defining the finished water quality parameters and goals is precisely the role of a water advisor. No one other than a water advisor could possibly define the finished water quality parameters and goals.

The finished water quality is the water quality that results after implementation of the suggested recommendations for water treatment. To accomplish this task, LAN, as the City's water engineer, would have to review the EPA and Michigan water quality regulations, including the EPA Secondary MCL. This task requires sophisticated skills and judgment to evaluate the unit water treatment processes required to achieve those water quality goals based on the incoming water quality of the Flint River.

[redacted] Mr. Green's testimony further confirmed that LAN acknowledged that they were the water treatment advisor to the City of Flint in 2013 (Green 2020, Vol 3 p. 598:15-18). Mr. Ramaley argues that LAN's scope was reduced, thereby eliminating the water advisor role. The removal of this role from LAN's scope was not memorialized in any written documents that have been produced, including the contract change orders.

Mr. Ramaley goes so far as to claim that LAN had no role as a water adviser for Flint. Mr. Green's own testimony clearly contradicts this position, as he believed that the execution of the LAN/Flint contract initiated their role as a water treatment advisor (Green 2020, Vol 3 p. 599:29). While Mr. Ramaley argues that LAN's scope was reduced, as do portions of Mr. Green's testimony offered six years after the Flint Water Crisis, no written documents memorialize the abdication of LAN's role as the water treatment advisor. In fact, Mr. Green's testimony confirmed that no emails, memos, or language in the change orders exist stating that LAN was no longer serving as the water advisor.

When under contract in 2013, LAN's staff was the only engineer working for Flint that had a background in water treatment (Green 2020, Vol 3, pp.708:13-709:5). During this time LAN failed to identify the existence of highly corrosive water from the Flint River which was ultimate distributed throughout Flint, even though they designed a major overhaul of the Flint Water treatment plant. LAN created a risk to human health and property by failing to insist that a corrosion control evaluation be performed prior to the switch, which is evidenced by the treatment plant going into service without any corrosion control

analysis. LAN failed to recommend adequate or modern corrosion control, as evidenced by both the testimony of Mr. Green and EPA's Mr. Schock. These failures to require a corrosion control evaluation, combined with the failure to recommend adequate corrosion control, are the basis of LAN's failure of the to meet the standard of care.

[redacted]. While LAN appeared to focus on the important task of forcing the water to flow through the plant hydraulically, the process of defining the basis of design is far more complex than simply ensuring that the water flows through the plant. This task means that LAN was charged with showing a thorough knowledge of water quality management and the methodology to accomplish that task. A thorough evaluation and design of a corrosion control injection system would be the minimum output from this task. No one other than the City's water quality advisor could accomplish this task.

[redacted]. Again, these tasks are clearly included in the role of the water quality advisor, even in the most direct lay reading of these words. The contractor, LAN, was obligated to detail the end result of the modifications that are stated as water quality (including turbidity, hardness, taste and odor, and disinfection byproducts). These are the tasks that could only be addressed by the water advisor to the City of Flint, and LAN signed the contract to fulfill the City's water quality advising needs. Mr. Ramaley's positions do not provide an effective rebuttal of the opinion that LAN failed to meet the standard of care.

See the Ramaley Appendix, the Lawler and Katz Appendix, Appendix 1, and Section 4 below for additional analysis of these issues.

**Russell Opinion 2020-4: LAN's and Veolia's advice were below ethical standards for Professional Engineers and water treatment operators. LAN and Veolia failed to meet the first level of ethics rules of the National Society of Professional Engineers, namely: Hold paramount the safety, health, and welfare of the public.**

As discussed in Opinion 2020-3 above, the LAN Expert Mr. Ramaley argues that LAN was more protective of health than others involved in the Flint Water Crisis. This is not an appropriate basis for evaluating if LAN met the professional and ethical standards of holding paramount the safety, health, and welfare of the public. Mr. Ramaley attempts to shift LAN's professional and ethical responsibilities onto the government agencies, including the City of Flint and MDEQ, but fails to rebut my opinion. LAN was involved at a critical time in the year prior to the switch over and the treatment plant startup, which should have allowed them to make recommendations to avoid the Flint Water crisis. LAN could have made recommendations that protected the safety, health and welfare of the public, but LAN failed to do so. They failed to meet their engineering ethical standards, and failed to meet the standard of care.

The Veolia expert Bellamy argues that Veolia's "…recommendations…were protective of public health and met the standard of care." Bellamy supports this position by noting that "…the potential for lead corrosion was identified and appropriate recommendations were made to the [City of Flint]." This position is not supported by the evidence in this matter, and Bellamy does not effectively rebut that Veolia failed to hold paramount the safety, health, and welfare of the public, which resulted in their failure to meet the standard of care. As discussed at length in my 2020 report and Bellamy Appendix, Veolia did not protect the health and safety of the people of Flint. Veolia proposed methods to hide the corrosive water (polyphosphate), was aware of the potential for lead corrosion, and failed to address the critical issues of corrosion and elevated lead levels resulting from the corrosive Flint River water.

**Opinion 2020-5: LAN and Veolia failed to meet the standard of care when they did not provide advice to the City of Flint that would enable the City to meet all drinking water standards simultaneously.**

The water treatment plant and distribution system in Flint failed to simultaneously meet all the drinking water standards under the guidance of the LAN and Veolia engineers. Violations included bacterial contamination, which led to boil water notices, high levels of disinfection byproducts that exceeded the EPA mandatory standards, corrosivity, and high levels of lead in the drinking water that also exceeded the EPA mandatory standards.

The LAN expert Ramaley argues that "LAN's recommendation for full lime-soda softening and phosphate addition would have allowed for [Optimal Corrosion Control Treatment] and simultaneous compliance." As discussed at length in my 2020 report and the Ramaley Appendix, LAN's approach to corrosion treatment was antiquated, inadequate, and the treatment system they designed was based on faulty technical expertise. The treatment plant LAN helped redesign rapidly failed to meet treatment standards on multiple fronts. The positions presented by Mr. Ramaley are not supported by the evidence and do not successfully rebut this opinion.

The Veolia expert Bellamy argues that *"[Veolia] made appropriate and operational recommendations to protect public health in order to simultaneously comply with state and federal drinking water quality regulations, e.g., the [Disinfection Byproduct Rule], [Total Coliform Rule], and the Surface Water Treatment Rules."* What Professor Bellay misses is that the recommendations made by Veolia, such as continued and increased use of ferric chloride, were in opposition to the legal requirements for Flint to provide optimal corrosion control. Veolia further recommended the use of a polyphosphate to cover up the corrosion, which can often increase the corrosive nature of water. As discussed in my 2020 report and the Bellamy Appendix, Bellamy fails to rebut this opinion. Veolia did not provide recommendations that would meet the requirements for simultaneous compliance with all water quality standards, and as a result they failed to meet their standard of care.

**Russell Opinion 2020-6: The majority of houses in Flint were constructed before 1988, during the time when high-lead solder was still in use. As a result, nearly all homes have lead-containing plumbing components installed. These leaded plumbing components are subject to producing high lead levels in drinking water due to exposure to the Flint River water.**

The Defense experts do not rebut the opinion that the homes in Flint were mostly built before 1988 and therefore contain high-lead brass fixtures and, if plumbed in copper, leaded solder. The use of high-lead brass and leaded solder prior to 1988 is well established in the industry.

Professor Duquette, Professor Bellamy, Professor Gagnon, and Mr. Ramaley claim that the high-lead scales, primarily associated with lead laterals, were the dominant form of lead contamination in the City of Flint. In fact, the majority of homes in Flint (83 percent) did not have lead service laterals; however, during the Flint Water Crisis it was demonstrated by Pieper et al. 2018 that the majority of the lead contamination in the Flint homes came from corrosion of the high-lead brasses and leaded solder (over 70 percent). This issue is addressed further in both the *System-Wide Impacts* section of this report and the respective expert appendix sections.

**Russell Opinion 2020-7: The switch to the highly corrosive Flint River water directly resulted in significant damage throughout the City's and property owners' plumbing systems. This corrosive water was uniformly distributed to all homes and businesses located throughout the Flint water system. Negative impacts to the plumbing systems included: the loss of pipe wall thickness, the potential initiation of copper pipe pitting corrosion, and increased galvanic corrosion. These negative impacts on the plumbing components are permanent and have reduced the life of the homeowners' plumbing systems, the value of their homes, and the useful life of the plumbing components. The only way to restore the losses resulting from exposure to the corrosive Flint River water is full house pipe and fixture replacement.**

The LAN experts, and the Veolia experts Professor Bellamy and Professor Gagnon, do not successfully contest that damage occurred to the plumbing systems throughout Flint. These experts do not successfully contest that this damage needs to be repaired. These experts do not contest that the same corrosive Flint River water was distributed throughout the City of Flint.

The Veolia expert Professor Duquette argued that:

- *visual examinations of the internal plumbing in representative homes in Flint indicated no observable corrosion damage to any of the plumbing supply lines or fixture*
- *[e]xposure to Flint River water did not accelerate metal corrosion damage to the distribution system or homes within it*
- *and that protective scales prevented effectively all corrosion*

The inspections referenced by Professor Duquette only examined the outside of the pipes, and these inspections were documented with photographs that clearly indicate leaks and corrosion as discussed in Section 5 below and the Duquette Appendix. The claims that corrosion did not occur, or accelerate, on the metal plumbing systems is inaccurate and not supported by the evidence. The "protective scales" began to destabilize immediately following the change to Flint River water, and there is no evidence that these scales were thick enough (they were on the order of the thickness of a sheet of paper according to Professor Duquette's speculation) to provide an impenetrable barrier against corrosion throughout Flint.

In fact, the appearance of red water immediately following the change in water sources suggests that the destruction of these scales, and corrosion of the underlying iron and steel pipe, began immediately. Professor Duquette argues that there is no evidence of damage that would necessitate replacement of household plumbing. As is discussed in the Duquette Appendix, this position is not supported by the evidence collected during the Flint Water Crisis. In fact, as noted above, Professor Duquette's own photographs show a reduction of pipe wall thickness via evidence of through-wall pits.

The Defense experts for LAN and Veolia fail to provide a compelling rebuttal and supporting evidence to counter my opinion.

**Russell Opinion 2020-8: At this point, lead and lead-containing materials (i.e., scales and particulates) are present in the plumbing systems throughout Flint. These lead-containing plumbing materials include: lead service laterals, high-lead brass, high-lead solder, lead pigtails (cast iron piping distribution system), galvanized pipe, and high-lead content scale in PVC and copper piping.**

**This lead will be released episodically due to changes in water flow rate, plumbing repairs and replacements, and changes in drinking water chemistry. These releases cause ongoing lead exposure to the residents of Flint.**

The Defense experts for LAN and Veolia do not refute that lead-laden scales and lead-containing plumbing materials are present throughout the plumbing systems of Flint. While the lateral replacement program in Flint has removed many lead and galvanized service laterals, that work has done nothing to address the lead issues that remain inside of the premise plumbing, which impacts the essentially all of the Flint homes and businesses.

The Veolia expert Professor Duquette addresses the second part of this opinion regarding the ongoing exposure of lead from these impacted plumbing components. Professor Duquette claims that this ongoing source of lead has been mitigated based on the sewage sludge lead analysis performed by Roy et al. As discussed in detail in the Sewage Sludge Appendix, the sewage sludge analysis, and the associated modeling efforts which Professor Duquette bases his opinion on, are flawed and incorrect. Further, Professor Duquette's central position is that the pipe scales in Flint remained throughout the Flint Water Crisis. While there is clear evidence this did not occur throughout Flint (recall that the majority of homes in Flint had elevated levels of lead from corrosion associated with other sources than lead laterals), he is conceding that lead-laden scales are still present throughout the plumbing systems in Flint and the only way to remove them is by installing new lead free plumbing and fixtures. Professor Duquette fails to successfully rebut that lead-containing materials are present throughout the plumbing systems in Flint, and that these lead containing materials produce ongoing lead releases.

**Russell Opinion 2020-9: Every home and business in Flint received the highly corrosive Flint River water from April of 2014 through at least October 2015. The exposure to Flint River water impacted plumbing components by accelerating corrosion and increasing lead release into the drinking water. Every home and business suffered property damage to the premises plumbing and the residents were exposed to elevated levels of lead and iron in their drinking water. As a result of exposure to the Flint River water, all homes would have had endured one or more of the following issues:**

**(1) corroded galvanized pipe**

**(2) corroded high-lead brass fixtures**

**(3) pitted/corroded copper pipe**

**(4) corrosion at dissimilar metal connections [leaded solder-copper, brass-steel]**

**(5) particulate lead and/or lead containing pipe scale inside of the premise pipes, including those constructed of steel, copper, and plastic**

The LAN experts, and the Veolia experts Professor Bellamy and Professor Gagnon, do not successfully contest that damage occurred to the plumbing systems throughout Flint. These experts do not successfully

contest that this damage needs to be repaired. These experts do not contest that the same corrosive treated Flint River water was distributed throughout the City of Flint.

Professors Bellamy, Gagnon, and Duquette concede that particulate lead was present in many homes in Flint. They concede that the particulate lead and was a source of elevated lead in the water, especially in those homes with lead service laterals.

As discussed in the analysis of Russell 2020 Opinion-8, the Veolia expert Professor Duquette fails to provide an effective rebuttal to my opinion that plumbing system corrosion damage occurred in Flint. The evidence collected in Flint, such as the site inspections presented by Professor Duquette and the published literature from the work performed by the Edwards Team from Virginia Tech, confirms both the presence of these plumbing materials and the fact that corrosion occurred in these plumbing materials (high lead in the drinking water samples of over 85 percent of the homes sampled [Pieper et al. 2018]). Further analysis of this issue is presented in the Duquette Appendix.

As documented in my 2020 report, essentially every home in Flint contained plumbing components that were negatively impacted by the corrosive treated Flint River water. This finding is not successfully rebutted with supporting evidence by the LAN and Veolia experts.

**Russell Opinion 2020-10: LAN should have requested written direction from the City before abdicating its role as the City's water treatment advisor. LAN should have clearly communicated to the City that it was abdicating this role.**

The LAN experts Lawler and Katz do not contest this opinion.

The LAN expert Mr. Ramaley argues that "[no] water advisor role was ever described, assigned or allowed to be filled by LAN." While I do not agree with Mr. Ramaley's position that LAN had no responsibility for the treated water quality from the Flint River (See discussion of Russell Opinion 2020-3 above), he also fails to effectively rebut this opinion. Mr. Ramaley chooses instead to rely on a flawed scope of work analysis, in which he ignores critical aspects of LAN's contractual obligations, LAN's testimony, and their increased fees under the Change Orders. His analysis ignores LAN's obligations as an engineer and technical adviser to the City of Flint, which demonstrates their failure to meet the standard of care. Additional analysis of these issues is provided in the Ramaley Appendix.

**Russell Opinion 2020-11: As the engineer, it was LAN's responsibility to recommend the completion of an Optimal Corrosion Control Treatment study before the switch, and its failure to do so did not comport with its professional obligations.**

The LAN experts Lawler and Katz do not contest this opinion.

The LAN expert Mr. Ramaley argues that, with regards to a *corrosion control study* "[o]n several occasions, Warren Green offered to implement water quality studies that could have led to this type of information in an accelerated fashion." I do not agree that Mr. Green's approach to corrosion control was acceptable or adequate. I take issue with Mr. Ramaley's claim that this work could have achieved the required information of a corrosion control study in an *accelerated fashion*. I am not aware of the existence of any work plan or written proposal to this effect.

To make his case, Mr. Ramaley relies on witness testimony from six years after the fact, as there was no contemporaneous documentation of the LAN work product available to support his position. Mr. Ramaley provides neither evidence that LAN proposed a corrosion control study prior to the switch, nor any adequate evidence that LAN met their professional obligations with regards to the subject of the legally

required implementation of an Optimal Corrosion Control Treatment system. Accordingly, Mr. Ramaley fails to provide the evidence to rebut my opinion.

# 3 What Happened in Flint

The Flint Water Crisis happened.

The City of Flint provides a single water source. All homes and businesses throughout Flint received the same undrinkable water, with effectively the same poor water quality, during the Flint Water Crisis. Prior to the Flint Water Crisis, the City of Flint water had purchased from the Detroit Water and Sewer District (DWSD) since 1967.

The water provided by DWSD was treated Lake Huron water. The DWSD water was stable and treated with Optimal Corrosion Control Treatment, as was required by law. This treatment consisted of adding an adequate dose of orthophosphate, based on the work of the DWSD consultants in 1992. In fact, Veolia served as a water quality consultant for the DWSD during this time period of the Flint Water Crisis. Orthophosphates are the primary industry-standard method to provide supplemental corrosion control in drinking water systems. The orthophosphates encourage the formation of stable scales that protect the metallic pipes from corroding and alter the surface chemistry of the metallic components. Orthophosphate is effective and economical to install and to operate.

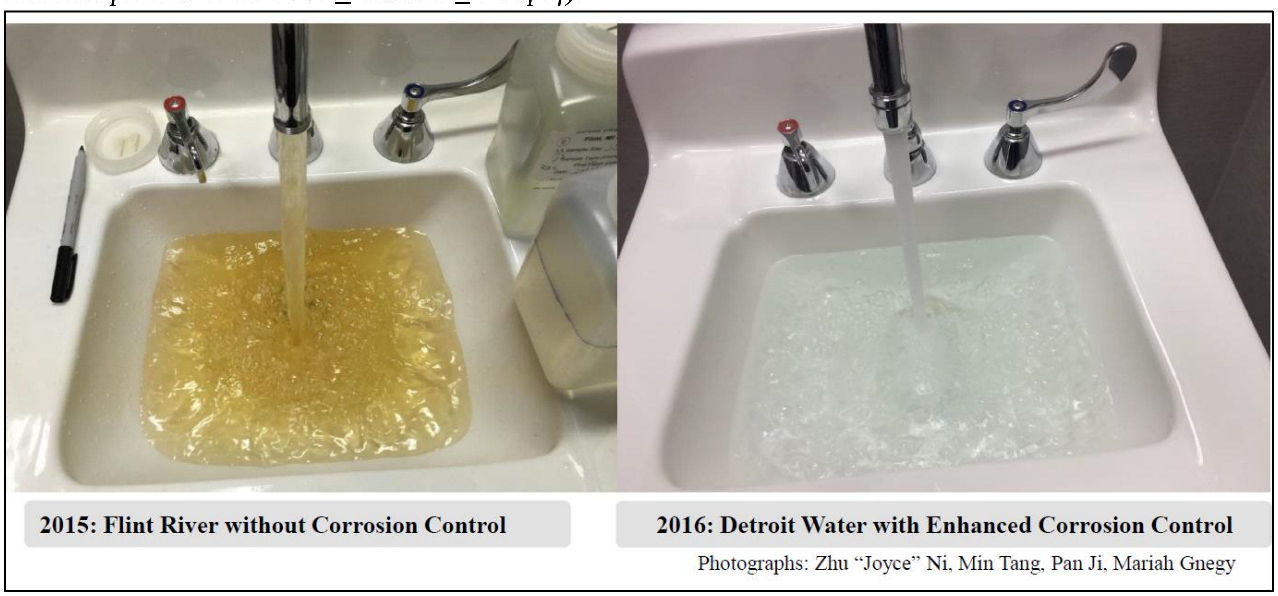
The Flint Water Crisis began immediately following the change from DWSD water to Flint River water, which was treated at the Flint Water Treatment Plant. This water was not treated to provide modern corrosion control (let alone optimal corrosion control), and was corrosive to the pipe scales and plumbing components located throughout the City of Flint.

Shortly after the switch to Flint River water, problems with corrosion were reported by the residents, which included red water complaints. The red water was generated by the formation/release of iron oxides (rust) from the plumbing system including the City's cast iron mains and the household galvanized steel piping. Red water is a clear indicator of an out-of-control corrosion process occurring within a water system.

The impact of the high levels of corrosion experienced during the Flint Water Crisis is clearly shown in the two photos below, which were taken during Flint Water Crisis. These images show the impacts of the Flint River water, and how the water quality improved following the return to DWSD in 2016 (right image in Figure 3.2).

*Figure 3.1: Images of discolored water samples collected in a home in Flint Michigan in January 2015 during the Flint Water Crisis. (Time.com <u>See What Flint's Poisoned Water Looks Like January 21, 2016</u>;FlintWaterStudy.org; https://time.com/4189116/flint-michigan-water-study-photo/)*


*Figure 3.2: During (left) and post (right) Flint Water Crisis in McLaren hospital in Flint. (Flint Water Press Conference, December 2, 2016, Virginia Tech; http://flintwaterstudy.org/wp-content/uploads/2016/12/VT_Edwards_12.2.pdf).*




The Flint River water was so corrosive to metallic components that the General Motors (GM) engine assembly plant in Flint had problems with the unacceptable corrosion of their engines on the manufacturing line. In December of 2014, the City paid for a separate connection to return the DWSD water to GM, but this corrosive water continued to be provided to all households and business throughout Flint during the Flint Water Crisis.

# 4 LAN and Veolia Could Have Averted Much of the Harm in Flint

LAN and Veolia neither adequately addressed, nor reacted to, the highly corrosive conditions in the water system. LAN and Veolia failed to apply the needed expertise to solve all the City's water quality problems. It appears that the LAN and Veolia professionals simply ignored their representations to Flint, and their professional/ethical obligations to protect the public health. LAN and Veolia failed to provide the expertise to implement adequate corrosion control in Flint. Had adequate, modern, optimized corrosion control been implemented, the damage in Flint could have been substantially reduced during the Flint Water Crisis.

## 4.1 LAN's Scope and Role

LAN was the primary engineering consultant supporting the City of Flint through the re-commissioning of the Flint Water Treatment plant. The work of the LAN engineers had been ongoing since the 1990s, and critically ramped up during the one-year period immediately leading up to the Flint Water Crisis. In the spring of 2014, the Flint River water was distributed throughout Flint. LAN was providing the technical expertise needed by the City to restore the operation of the FWTP prior to switching to the Flint River water. During this period, the treatment plant was allowed to go into service without the necessary equipment, control systems, or a modern (and adequate) corrosion control treatment program, and the plant was being operated by insufficiently trained water treatment personnel.

As one of LAN's experts, Mr. Ramaley attempts to argue that LAN had no role as a "water advisor," and therefore had no role in the water quality and the corrosive Flint River water that was produced by the treatment plant. This position is unsupported and inaccurate. LAN was *the* only technical expert assisting the City of Flint with bringing the Flint Water Treatment Plant online. As discussed in the analysis of Russell Opinion 2020-3 above, LAN was tasked with role of the water advisor in their contract with Flint. LAN was in this critical position for years before the switch to Flint River water, and from that position they should have attempted to avert the Flint Water Crisis. Mr. Ramaley provides no convincing evidence that LAN did not have this role. My position on this matter is further supported in both the Ramaley Appendix and Section 2 above.

LAN continued to assist the City of Flint after the switch to the Flint River. That switch caused immediate and widespread observations of red water indicating excessive corrosion activity (see 3.1 and 3.2 above). That ongoing role placed LAN in a critical role that could have allowed them to avert much of the harm done by the Flint Water Crisis once the switch occurred, had they acted competently. LAN's technical recommendations resulted in helping the City to bring the treatment plant, with its corrosive water product, into service. The treatment plant produced water based on a LAN-designed treatment scheme, which lacked modern corrosion control.

As has been established, LAN's staff had an antiquated and inadequate approach to corrosion control (Russell 2020, pp. 45-46; Schock Deposition 2020, pp. 103:7-14). Based on my review of the documentation provided by LAN, there is no written evidence documenting any recommendations from LAN to install modern corrosion control. Similarly, there is no written evidence memorializing that LAN disagreed with distributing the corrosive Flint River water without corrosion control. Ultimately, LAN's engineering services did not avert the Flint Water Crisis, and their lack of competent engineering was one of the primary reasons it occurred.

As a result of actions taken by the City under LAN's guidance, such as the use of antiquated and inadequate corrosion control strategies, and LAN's non-actions regarding the corrosion problems, widespread impacts occurred throughout the City of Flint. These impacts included exposure of the residents to elevated lead levels and damage to the plumbing systems throughout Flint.

## 4.2 Veolia's Scope and Role

Veolia was brought into Flint in early 2015 as the sole bidder on the City of Flint's widely distributed Request for Proposals (RFP) to address water quality issues in the City of Flint. While their initial focus was on disinfection byproducts, their work—as explained further below—encompassed a much wider scope. Veolia subsequently failed to adequately identify or address both corrosion and other water quality issues in Flint.

The City of Flint's RFP, to which Veolia responded, set out a broad scope of work. Some of the details from that Request for [redacted] [emphasis added]:

[redacted]

In Veolia's response to the RFP, they claimed that they would comply with the above requirements and provide the following through their [redacted]):

[redacted]

The contract issued to Veolia utilized their proposal and the City's original RFP to define the scope. The contract between Veolia and Flint states ([redacted]):

[redacted].

While Veolia attempted to assuage the concerns of the public, they were in fact ignoring the very real consequences of the Flint Water Crisis, including increased exposure to lead and damage to the plumbing systems throughout Flint. Veolia was engaged at a critical time in the Flint Water Crisis and could have averted much of the damage that occurred, had they acted. Instead, Veolia provided recommendations to

dose the water with polyphosphate in an attempt to hide the red water discoloration. Veolia failed to address the root cause issues of corrosive water in Flint and failed to fix the corrosive nature of the water.

Veolia's experts, particularly Professor Bellamy, attempt to argue that Veolia had no responsibility regarding the corrosive nature of the water from the Flint River. As shown by Veolia's response to Flint's RFP and the contract between Flint and Veolia, that is clearly not the case. Veolia was hired to handle both "…[redacted]," to [redacted]. All of the above should have included addressing the ongoing corrosion that Veolia's experts admit Veolia was aware of.

Veolia was involved at a critical time during the Flint Water Crisis. Had Veolia met their Standard of Care, they could have averted much of the damage that occurred in Flint. Instead, Veolia chose to provide recommendations to hide the signs of corrosion and used their reputation to try and assure the public and the City officials that the water was safe. Clearly, the water was not safe, as was witnessed by the boil water notices the City issued, disinfection byproduct levels, and elevated levels of metals in the drinking water. Veolia failed to provide the technical expertise and sound engineering recommendations that could have limited the damage from the Flint Water Crisis, and as a result Veolia failed to meet their standard of care obligations.

# 5 System-Wide Impacts

All residents in Flint received the same corrosive water during the Flint Water Crisis, as there is only one source of water in Flint. Within hours or days (depending on location) of the switch from DWSD water to Flint River water, every business and resident received the corrosive treated Flint River water. Within days, that corrosive water began to dissolve the protective pipe phosphate scales (Schock Deposition 2020, Vol. I, p.108:5-p. 109:4; Schock Deposition 2020, Vol II, P. 344 L12-p. 345 L7), releasing heavy metals, like lead, into drinking water faucets throughout the City of Flint. Exposure to the treated Flint River water subjected the Flint plumbing systems to damage resulting from corrosion.

All Flint plumbing systems were impacted by the corrosive water during the Flint Water Crisis. The residents of Flint were subjected to elevated levels of lead (Pieper et al. 2018), which were measured in 85 percent of the homes sampled in August 2015 and which exceeded the State and Federal lead Action Levels. It is documented that the corrosion impacts extended well beyond those related to high-lead containing scales (such as in those homes with lead service laterals), and into houses without lead service laterals or galvanized iron pipe. This reality was demonstrated by Roy and Edwards in their 2020 research paper, wherein they reported that the *Resident X* home, which showed the highest lead levels measured in Flint during the August 2015 sampling round, <u>contained neither a lead service lateral nor galvanized piping as sources of lead</u>. Their findings clearly indicated that lead in these homes (83 percent), which were the majority of Flint homes (only 17 percent of the homes had LSLs), was coming solely from the corrosion of lead in their high-lead brass faucets and fittings and from the corrosion of leaded solder in copper plumbed homes. Additionally, the lead in the *Resident X* home's drinking water was determined to have come from new corrosion (as opposed to scale degradation) resulting from corrosion of the leaded solder and high-lead brass (Roy and Edwards 2020, p. 3027).

Obviously, houses with lead service laterals had large sources of lead in their plumbing systems via the destabilization of the high lead phosphate scales. The impacts of those large sources of lead on Flint drinking water quality at the faucet was well documented in the *Resident Zero* house which had a combination of a long lead service lateral followed by a galvanized service lateral and then corrosion inert plastic internal premise piping (Pieper, Tang, and Edwards, 2017). The *Resident Zero* household had extensive issues with lead contamination (measured at over 230 times the lead Action Level) and with red water (see Figure 3.1 above, which shows water that was collected from within this household). As was demonstrated by the Edwards Team in their 2017 paper, the *Resident Zero* internal pipe scales in the plastic household pipes were destabilized and released into the tap water during the Flint Water Crisis. This release served as a form of particulate lead in the Flint drinking water leading to highly elevated levels of lead in their drinking water.

However, there are other critical sources of lead that impacted the majority of homes in Flint, including the majority of those which are <u>without</u> lead service laterals. It has now been determined that only 17 percent of the homes had lead service laterals, but essentially all of the homes in Flint had (and still have) many other high-lead plumbing components like faucets. These other lead-containing components were a critical source of lead in the Flint drinking water, as demonstrated by the fact that the majority (85 percent) of the homes had lead concentrations that exceeded the EPA Action Leve of 15 ppb during the August 2015 sampling round. This corrosion impacted essentially every building in Flint, and consequently the drinking water provided to essentially all Flint residents. These other lead sources have been estimated by Roy and Edwards to be the source of between 16-28 percent of the lead exposure throughout Flint (Roy and Edwards 2020, p. 3028) in the buildings with a lead service lateral. In the

houses without a lead service lateral, obviously 100 percent of the lead originates from the corrosion of these sources, including high-lead brass and/or leaded solder, as there are no other sources of lead in the home. The critical role these in-home sources of lead played in causing high-lead levels in the tap water is documented in my original expert report and in the data from homes like that of *Resident X*, which was extensively analyzed by Roy and Edwards 2020. As stated by Dr. Masten, under the water conditions in Flint, "…lead release from … solder is quite high" (Masten, Haider, and McPherson 2019; Arnold 2011).

This data directly contradicts the opinions of Professor Duquette, Professor Bellamy, Professor Gagnon, and Mr. Ramaley, who state that the high-lead scales were the dominant form of lead contamination in the City of Flint. As demonstrated by Pieper et al. 2018, the majority of the lead contamination in the Flint homes came from the corrosion of the high-lead brasses and high-lead solder, and not from the high-lead scales.

The high levels of lead in the plumbing components were confirmed during Defendants' inspections of two of the named plaintiffs' homes, performed by Dr. Crowe. Defendants utilized an instrument called an XRF, which uses x-rays to analyze for metals. They found that most of the plumbing components located throughout the Flint houses contained lead well in excess of current EPA lead standards for faucets and solder. These plumbing components provided a significant source of lead to the residential drinking water in Flint, which directly contributed to the high levels of drinking water lead observed during and after the Flint Water Crisis. Additionally, these two inspections showed that both homes' pipes and plumbing systems had obvious evidence of corrosion (see Figures 5.1 and 5.2 below). This evidence includes through-wall leaks (pipe failure) and galvanic corrosion at the mating of dissimilar metals (i.e., galvanized steel to brass connections and/or high-lead solder used to sweat copper pipe connections).

*Figure 5.1: Example of leaking galvanized steel pipe from a home in Flint as documented by Defendants (Duquette Underlying Data, [redacted] CPI Inspection Report). Note the original image file is presented with a red arrow added at the location of the through pipe wall leak.*

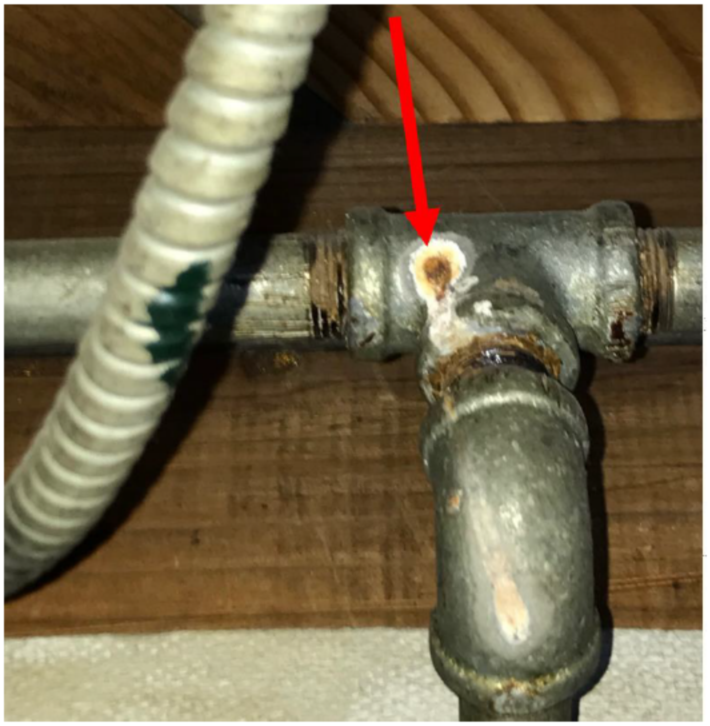
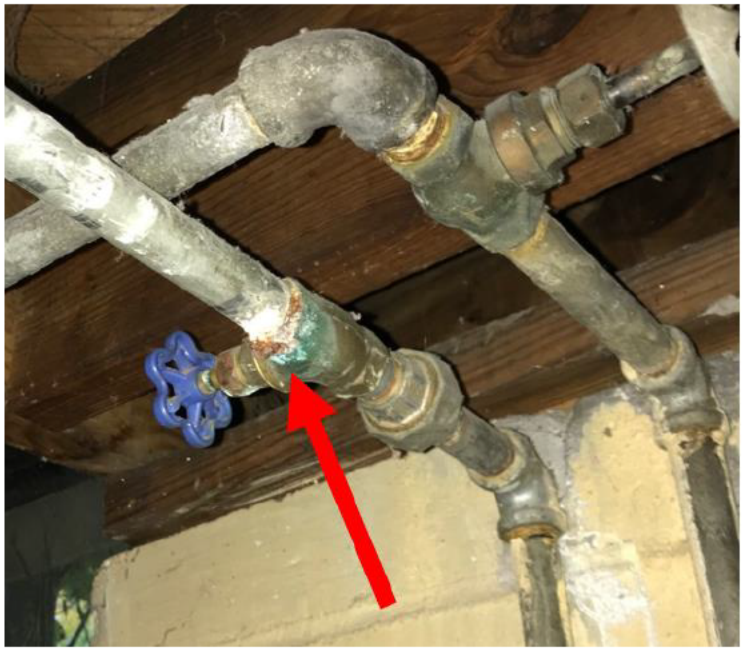


*Figure 5.2: Example of a leak formed at galvanic couple between galvanized steel and brass from a home in Flint as documented by Defendants (Duquette Underlying Data,* [redacted] *CPI Inspection Report). Note the original image file is presented with a red arrow added at the location of the through wall leak.*



There are a variety of lead sources in the homes in Flint. These include lead released from scales on service laterals, and in-home sources such as destabilization of leaded scales, and galvanic corrosion, as detailed in my 2020 report Sections 7 and 10. Regarding the in-home scales, the water provided by DWSD since the 1990s was treated with orthophosphates under an optimal corrosion control treatment program which has minimized corrosion for decades. That water created protective scales throughout the plumbing systems in Flint, and these protective scales contained high levels of lead in many homes and businesses. During the Flint Water Crisis, the corrosive water from the Flint River (which was not treated with corrosion inhibitors) destabilized these scales, and then corroded the exposed high-lead brass and leaded solder. The destabilized scales and the lead corrosion products were released into the water and contaminated that water with lead and other heavy metals.

The LAN experts, and the Veolia experts Professor Bellamy and Professor Gagnon, do not adequately contest that damage occurred to the plumbing systems throughout Flint. Commensurately, they do not adequately contest that this damage needs to be repaired. These experts also do not contest that the same Flint River water was distributed to all homes and businesses in the City of Flint.

Professors Bellamy, Gagnon, and Duquette concede that particulate lead was present in many homes in Flint and was a source of elevated lead in the water. Professor Duquette claims that plumbing scales established prior to the Flint Water Crisis protected all of the pipes and plumbing components from corrosion and damage, but this theory is plainly incorrect. As discussed in Section 2 above and the Duquette Appendix, his position is not supported by the scientific data collected in Flint.

In their reports, the Defense experts provide no opinions that either address or succeed in undermining the existence of the common issues that I demonstrate in my original report, and that form the basis of the

characterization of the Flint water users as a Class. Residents and businesses throughout the City of Flint were all impacted by the corrosive water during the Flint Water Crisis.

# 6 Ethical Requirements of Civil Engineers and Expert Qualifications

Some questions have been put forth by the defense regarding my qualifications, particularly with regard to the determination of the engineering standard of care and engineering ethics. My expert qualifications were presented in my 2020 report in Section 3. I have gained substantial experience in the ethical and standard of care requirements for Civil Engineers through my experience of being registered as a Civil Engineer since 1977 and having worked on over 1,000 projects during my career. Additionally, I have worked as an expert witness in litigation matters representing both engineering defendants and plaintiffs on issues of professional engineer's conduct. I have worked on over a dozen such litigation matters.

Some additional details follow for further clarification. I have worked for over 45 years in the fields of water quality, corrosion control, the selection of materials, materials performance, and materials failure evaluations, and I have a solid reputation as a fearless proponent of the canons of engineering ethics. I have previously testified in multiple matters, for both defendants and plaintiffs, regarding the standard of care for professional engineers. I am experienced in engineering ethics determinations, and I routinely participate in engineering ethics courses and professional discussions as part of the continuing education programs associated with my professional engineering registrations. I have qualified for professional engineering registration in numerous states by endorsement, and many of those states required that I pass a written multiple question engineering ethics exam prior to award of my engineering license by endorsement.

As undergraduate students, civil engineers are trained on the ethical requirements of engineers. My training at the University of California at Berkeley consisted of a mandatory class on engineering ethics. Additionally, many states, including many states in which I am registered, require updated ethics training every two years to be eligible to renew one's professional engineering license. As a result of this requirement, I've taken dozens of ethics training courses over my career. In addition, as an elected water board director of the Marin Municipal Water District, I have taken State of California mandated ethics training modules every two years since 2004.

# 7 Conclusions

My 2020 expert report provided eleven opinions related to LAN, Veolia, and the Flint Water Crisis. Those opinions addressed four primary aspects of the Flint Water Crisis.

i) Applicable engineering standard of care
ii) Breach of the engineering standard of care
iii) Evidence of harm to the plumbing systems and water quality throughout Flint
iv) Evaluation of the conditions that qualify the residences and businesses of Flint to be characterized as a Class

The Defense experts ultimately fail to rebut the opinions presented in my 2020 report and my subsequent deposition. They fail to establish that LAN and Veolia met the standard of care related to corrosion in Flint. They fail to rebut or contest the existence of common issues, which were experienced throughout the City of Flint, and which characterize the members as a Class.

One of the primary roles of my report expert report was to evaluate, memorialize, and explain the common issues which affected the residents of Flint during the water crisis, and to provide support for their certification as a Class. As discussed and demonstrated in this report, and in the associated expert-specific appendix reports, defendants' experts utterly fail to undermine my opinions regarding the existence of classwide issues.

The defendants and their experts focus most of their analysis on disputes of the applicable standard of care. Where the Defense experts actually address the appropriate standard of care issues, they fail to provide a convincing and supported argument that LAN and Veolia did in fact meet the required standard of care. I have demonstrated in my Expert and Rebuttal Reports that LAN and Veolia did not meet the applicable standard of care, and I do not concur with the concept that the work performed by LAN and Veolia under their respective contracts was equivalent to the care and skill ordinarily used by members of the civil engineering profession who practiced under similar circumstances to those in Flint in 2013-2015.

None the less, the opinions presented by those experts actually confirm the class-wide nature of the water issues in Flint, as I opined. They offer no objection to the fact that every property in Flint was exposed to the same corrosive water during the Flint Water Crisis. They also offer no reliable evidence in opposition to the fact that there was damage to all of the plumbing systems located throughout Flint as a result of the switch to the corrosive treated Flint River water without proper corrosion control. The authors of these reports simply provide speculative conclusions that generally ignore the extensive body of evidence that opposes their position.

LAN and Veolia were each in a role through which they could have provided sound engineering advice that would have either avoided the Flint Water Crisis (LAN) or could have averted a substantial portion of the harm resulting from the Flint Water Crisis (LAN and Veolia). As discussed by the experts for LAN and Veolia, the engineering required to prevent or avert the damage of the Flint Water Crisis simply wasn't provided to the City. As is clearly evident by the results of the Flint Water Crisis, both LAN and Veolia failed to meet their professional obligations and failed to meet the standard of care for professional engineers and their engineering companies.

# 8 Signature and Stamp

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge and recollection.

Executed this 29th day of March, 2021, in Tiburon, CA.

By:

Larry L. Russell, Ph.D., P.E.

STATE OF MICHIGAN
LARRY
RUSSELL
ENGINEER
NO.
55338
LICENSED PROFESSIONAL ENGINEER

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# 10 Appendices

Appendix 1: Rebuttal Report of Larry L. Russell: Supporting Information

Appendix 2: Analysis of Ramaley Reports

Appendix 3: Analysis of Lawler and Katz Reports

Appendix 4: Analysis of Bellamy Declaration

Appendix 5: Analysis of Gagnon Declaration

Appendix 6: Analysis of Duquette Declaration

Appendix 7: Analysis of Edwards's Sewage Sludge Data

**Appendix 1**

**Rebuttal Report of Larry L. Russell: Supplemental Information**

# 1 Introduction

This Appendix provides supporting information and additional details related to the main Russell Rebuttal report. This Appendix addresses a number of specific issues raised by the Defense experts, many of which were shared across multiple reports. As will be detailed below, these specific issues are diversionary and neither address nor undermine the opinions presented in the Russell 2020 report.

The experts for LAN and Veolia attempt to raise a number of issues regarding the opinions I expressed in both my written report and my depositions. In general, these arguments are attempts to divert the reader's attention away from the real issues and the classwide impacts to the residents of Flint. Additionally, the experts misrepresent the available information by selective editing and omitting available information that is counter to their opinion.

These experts ultimately fail to address what occurred in Flint and what caused it to occur. These expert reports fail to undermine or rebut the core issues related to class-wide impacts and damage caused by the corrosive Flint River water in Flint. This section provides a brief overview of some of the issues raised in the LAN and Veolia Expert and Rebuttal Reports, and explains why those reports fail to undermine the classwide impacts of the Flint Water Crisis. A detailed analysis of each expert report, including many of these diversionary issues, is presented in the appendices to this report.

This Appendix also includes a short evaluation of the Edwards Sewage Sludge studies from Flint. The conceptual model upon which these studies relied was fundamentally flawed, missing the critical influence of lead accumulated in the sewer solids. This section highlights how the Defense Experts relied on this data to make their case, and briefly explains that the Edwards analysis is neither accurate nor reliable for this use. Therefore, the conclusions drawn by the Defense Experts utilizing this data are flawed and unreliable.

Additional information supporting this section is presented in the expert-specific appendices which follow.

# 2 The Highly Corrosive Nature of the Flint River Water

The Defense expert reports attempt to take issue with terminology I used in the Russell 2020 report to describe the corrosive nature of the water in Flint during the Flint Water Crisis. These experts take issue with terms used in the Russell report, such as *highly corrosive*, claiming they are not consistent across the industry. This argument is a distraction from the core issues:

1) Was the water corrosive? **Yes.**
2) Was that corrosive water distributed throughout the City of Flint? **Yes.**
3) Did that corrosive water damage plumbing systems? **Yes.**

The science on corrosive water is well established and beyond dispute. The photographic and scientific evidence collected in Flint speaks for itself: the water in Flint was corrosive. The corrosive nature of the water in Flint can be readily seen even by non-experts, as seen in Figures 3.1 and 3.2 in the Russell Rebuttal Report.

During the Flint Water Crisis, corrosive water was distributed through the City of Flint. This water damaged piping systems throughout the City and resulted in increased concentrations of lead and other metals. The Flint Water Crisis happened, it happened to all residents and businesses, and it was well documented. The Flint Water Crisis was avoidable and was a tragedy for the residents of the City of Flint. Whether the water is referred to as *highly corrosive* or some other term describing the nature of the water is irrelevant. The water was corrosive and it damaged the plumbing systems throughout Flint.

# 3 The Role of Corrosion Indices

The Defense Experts attempt to raise a variety of issues with the use of corrosion indices. These efforts are diversionary, and are an attempt to distract the reader from the fact that the water in Flint was corrosive and this corrosivity was both identifiable and predictable. The criticisms range from suggesting that the indices did not need to be calculated (as Veolia was well aware the water was corrosive), to claiming that the indices are not reliable or informative, and therefore were not important to calculate. Neither of these positions are correct. The corrosion indices are used by all competent corrosion engineers to provide a quick analysis of the water quality. The science on corrosion indices is well established and they are one of the most critical tools available to engineers when evaluating water systems. The corrosion indices should have been calculated in Flint by both LAN and Veolia. The results of these calculations would have informed a competent engineer that there was a critical need for corrosion control.

Corrosion indices are simple and quick tools that provide insight into the tendencies of water towards or against corrosive behaviors based. These indices are based on empirical (observed correlation) and/or scientific bases (See Russell 2020 for a comprehensive overview). CSMR, or the Chloride Sulfate Mass Ratio, is one of the corrosion indices available and should have been considered by the engineers in Flint. CSMR has proven useful in multiple locations for assessing corrosion tendencies, and would have helped the engineers in Flint identify the corrosive tendency of the water, and the need for sound engineering guidance on how to reduce or eliminate those impacts. The corrosion indices are a critical tool to determine if a given system is at risk of corrosion. In the absence of a thorough corrosion control study, these indices are an essential tool for corrosion assessment and prevention.

Corrosion indices consist of straight forward tools (calculations) that take into account various constituents of the water to determine a characteristic value. They are calculated based on the water at a given time relying on either advanced chemistry or empirical operations. The indices indicate a propensity of the water towards being corrosive. The various indices have defined regions whereby the corrosivity of the water is more of a concern or less of a concern. These critical thresholds, for a given corrosion index, are either determined based on the fundamental chemistry or empirically (based on observed data). The data is very well documented on this general subject since at least 1936, and on the issue of the value of CSMR since at least 1983.

Corrosion indices are used by all competent engineers experienced in corrosion mitigation and control. The importance of these indices is well documented in the industry, including by Professors Edwards and Masten who have performed extensive work related to the Flint Water Crisis. Corrosion indices are one of the industry standard tools in the field of water quality management. They are a critical tool to aid competent corrosion mitigation engineers.

As stated by Dr. Masten in her 2016 paper titled, *Flint Water Crisis: What Happened and Why?*

*The high values of CSMR and Larson-Skold indexes of water entering the Flint distribution system should have raised serious concerns about the possibility of corrosion, especially given prior experiences by water utilities (Masten et al. 2016, p. 30).*

As documented by Masten, and many others, CSMR was well established in the period leading up to and during the Flint Water Crisis, and should have been applied in Flint. Expanding on this point, the Masten

paper states that "[c]ommonly used indexes could have predicted that the treated Flint River water would likely corrode lead pipes" (Masten et al. 2016, p. 31).

The defense's reports try in multiple ways to criticize my understanding and interpretation of the corrosion indices. These criticisms lack foundation, they lack logic, they are unsupported, and they are simply wrong. If the engineers of LAN and Veolia were as knowledgeable as they are purported to be in the defense's reports, they would have routinely calculated the corrosion indices and documented those calculations. The indices take minutes to calculate, and as reported by Masten et al. 2016, the indices could have been used to avoid the Flint Water Crisis (LAN) or raise an urgent red flag about the ongoing situation in Flint during the Flint Water Crisis (LAN and Veolia). The indices could have been just the tool to raise a red flag and point the City in the direction of concerns about the role of corrosion and its impacts on public health (e.g., lead poisoning).

In fact, Professors Lawler and Katz acknowledge in their report that "CSMR is widely used by practicing engineers to flag possible corrosion" (Lawler and Katz 2021, p.9). Professors Lawler and Katz continue to state that "[w]e acknowledge that a careful reading of the research literature published prior to 2013 specifically about CSMR would lead to an understanding that this ratio might be a parameter to consider if one were concerned about lead corrosion" (Lawler and Katz 2021, p. 2). In contrast to this position, Veolia's expert Professor Bellamy claims that (Bellamy 2021, p. 44):

*[C]alculating CSMR would have been superfluous because (a) VEOLIA had already determined the potential for lead release … (c) calculating CSMR would not provide additional information on [Veolia's] determination that there was need for corrosion control treatment.*

Professor Bellamy argues that Veolia already knew that the water was corrosive and therefore calculating CSMR would not have provided it with additional information. His statement ignores the science and literature on CSMR which identifies its particular role in galvanic corrosion assessments, as opposed to the other information that Veolia used to determine that the corrosive water had the "potential for lead release." Further, Professor Bellamy's statement in fact proves the important nature of having calculated the CSMR. This information would have confirmed the Flint River water was a *serious concern* for corrosion, and would have prompted a competent engineer to investigate corrosion.

While the Defense Experts attempt to minimalize the role of CSMR, it is clear that corrosion indices are an essential tool in the industry and would have been employed by any competent engineer evaluating the water in Flint. When calculated using data from the treated Flint River water, the corrosion indices would clearly have raised a red flag. The indices suggested that the water would likely be corrosive (especially when combined with the documented problems that the City's largest employer [General Motors] was having with corrosion). The Flint River water was corrosive to the water piping systems throughout the City of Flint. Clearly the corrosion indices are important, and should have been utilized by the engineers working in Flint. Claims by the Defense Experts to the contrary are unsupported and inaccurate.

# 4 Corrosion Control Standard of Care

The Defense expert reports attempt to show that LAN and Veolia met the engineering Standard of Care regarding providing corrosion control in the City of Flint. As discussed at length in my 2020 expert report, and this rebuttal report with Appendices 1-6, LAN and Veolia did not meet the standard of care. LAN and Veolia were both providing technical expertise to the city of Flint either before or during the Flint Water Crisis. LAN and Veolia engineers were hired to provide the City of Flint with the technical guidance the City severely lacked. Yet, these same engineers did not prevent or mitigate the Flint Water Crisis. The recommendations made by LAN and Veolia did not meet the standard of care with regards to Corrosion Control.

The Flint Water Treatment system never provided modern corrosion control throughout the Flint Water Crisis. The Flint water system was unable to control critical water quality parameters, such as pH and alkalinity, and was not equipped to provide corrosion control chemicals (i.e., orthophosphates). Orthophosphates are a critical tool in modern corrosion control. Orthophosphates have been used by DWSD since the 1990s, and are commonly used in water systems across the country. If LAN/Veolia had pushed for using high doses of orthophosphates in Flint, that single action might have averted the Flint Water Crisis. Their use would have substantially reduced the problems in Flint, and helped stop the uniform attack of the corrosive water on the plumbing systems which impacted the residents and businesses throughout City of Flint.

Neither LAN nor Veolia provided sufficient guidance or recommendations to provide modern corrosion control at the Flint Water Treatment Plant. The defense's experts try to explain in multiple ways how LAN and Veolia recommended proper corrosion control. However, the truth is evident: these professionals simply did not provide the needed judgment nor expertise to the City of Flint, and as such they failed to meet the required Standard of Care.

LAN's experts make two central arguments regarding corrosion control and the work that LAN performed. Professors Lawler and Katz state that they were asked to comment on allegations that LAN failed to "…meet the standard of care in their work related to the Flint Water Treatment Plant in the time frame 2011-2014" (Lawler and Katz 2020, PageID 53633). Their core argument is that LAN recommended softening, which Lawler and Katz say "…fit within the guidelines for corrosion control that represented the state of knowledge at the time…" (Lawler and Katz 2020, PageID 53678). However, as stated by Lawler and Katz in their 2021 report, "…softening is not generally considered a primary means of corrosion control…" (Lawler and Katz 2021, p.7). Softening was the treatment method employed by LAN, and clearly it was not a corrosion control strategy that was adequate for the conditions in Flint. Lime based softening, which was recommended by LAN, is used primarily to address an aesthetic issue of the water quality named hardness. Lime addition water softening has never been and will never be a suitable corrosion control technique as discussed in the Russell 2020 report and Lawler and Katz Appendix.

LAN did not recommend a modern corrosion control approach, and the resulting corrosive water distributed throughout Flint speaks for itself as to the effectiveness of LAN's approach. As described by Mr. Schock of the EPA, the LAN approach to corrosion control was "…old 1930s, 1940s kind of corrosion control…" (Schock Deposition 2020, Vol. I, p. 71, L7-14).

Mr. Ramaley, the other LAN Expert, argues that LAN did in fact recommend corrosion control, including "phosphate." As evidence of this, Mr. Ramaley relies primarily on a single written document, a cost analysis, in the appendix of the 2011 Rowe Engineer's *Analysis of the Flint River as a Permanent Supply for the City of Flint*. If LAN had properly addressed corrosion in Flint, where are the documents supporting these analyses and where are the associated proposals to the City requesting approval for implementing an optimized corrosion control treatment system? To my knowledge, there are none.

Veolia's experts argue that Veolia was well aware of the possibility of corrosion in Flint. Professor Bellamy states that during Veolia's engagement, "Veolia identified [Lead and Copper Rule] compliance issues and possible corrosive water" (Bellamy 2021, p. 43). With regards to corrosion, Veolia's recommendations centered around using polyphosphates in order to hide the red color. These chemicals often accelerate corrosion, thereby making the situation even worse. They are not a corrosion control method. They are instead aimed at aesthetic improvements by hiding the discoloration associated with iron corrosion and release. As stated by Bellamy, "Veolia made the recommendation to add polyphosphate to help ameliorate the red water complaints" (Bellamy 2021, p. 59). A recommendation for polyphosphates does not meet the standard of care with regards to corrosion control.

Bellamy and Gagnon argue that Veolia also recommended the use of orthophosphate and a corrosion control study. Their support for this claim centers on the final report produced by Veolia for the City of Flint from March of 2015. In this report, Veolia only mentions corrosion control three times. In the body of the report, Veolia's only section on corrosion control states "[t]he water system could add a polyphosphate to the water as a way to minimize the amount of discolored water" (Veolia March 2015, p. 5). Veolia makes no reference to using orthophosphates, which undermines the claim that Veolia recommended orthophosphate-based corrosion control. Further, this section fails to discuss the urgent issue of the damage that this corrosion is causing throughout the City. Veolia's experts claim that Veolia was aware of corrosion concerns, but Professor Bellamy's arguments around Veolia providing recommendations for modern corrosion control hinge on a single line-item buried in the Veolia final report which recommended 0.5 mg/L (as P or $PO_4$?) dose of phosphate and to "…initiate discussion with state on addition of corrosion control chemical" (Veolia March 2015, p. 9-10). Veolia knew of the corrosive water in Flint, but failed to act to implement the required corrosion control. As a result of this non-action, Veolia failed to avert much of the harm caused to the residential plumbing during the Flint Water Crisis.

It is well understood that the treated water from the Flint River was more corrosive than the treated Lake Huron water purchased from DWSD (see Figure 3.2 in the Russell 2020 rebuttal report). Switching water sources is always a complex and challenging problem based on both aesthetic issues, such as taste, and based on corrosion control issues. These corrosion risks could have been mitigated by competent engineering, which includes corrosion control. When Veolia became involved in Flint, obvious corrosion issues were occurring throughout the City. Neither LAN nor Veolia did the work (nor exhibited the competence) to understand the corrosion processes in Flint. LAN and Veolia failed to provide a solution to stop the damage to the premise plumbing systems, the production of high levels of lead at the taps, and the associated distribution of corrosive and undrinkable water. Claims by the Defense Experts that LAN and Veolia met the standard of care with regards to corrosion issues in Flint are inaccurate, and not supported either by their actions or the resulting damage that was caused by the corrosive Flint River water.

# 5 Simultaneous Compliance

*Simultaneous compliance* is a requirement for water systems whereby they must meet all water quality regulations simultaneously. The Defense Experts for LAN and Veolia use simultaneous compliance to justify or applaud the work done by those engineers in Flint. This is a gross misapplication of the concept and requirements of simultaneous compliance. A careful review of the issues related to simultaneous compliance in Flint demonstrate that both LAN and Veolia failed dramatically in achieving this legal requirement. LAN and Veolia's Experts are misleading the reader and presenting the facts of the Flint Water Crisis in an inaccurate manner. The claims by the Defense experts regarding simultaneous compliance do nothing to undermine the opinions presented in my 2020 expert report.

Simultaneous compliance is the law, and it is not optional. The concept is that water systems must **simultaneously comply with <u>all</u> the water quality standards**. Water systems must comply 24 hours a day, 7 days a week, 365 days a year with all the water quality standards; the systems can't pick and choose, or prioritize one over another. It is the role of the regulators, such as the EPA, to determine the required standards which must be met. Corrosion control, especially for regulated poisonous constituents like lead, can never take a back seat to other constituents.

**Veolia's Failure to Provide Simultaneous Compliance**

The Veolia expert, Professor Bellamy, would have one believe that Veolia met the simultaneous compliance requirement solely by reducing the disinfection byproducts. This position is inherently contradictory with the principle of simultaneous compliance, as their recommendations failed to meet even minimum corrosion control requirements (let alone optimized corrosion control requirements), and in fact made the corrosion in Flint worse. Through their actions, Veolia was necessarily violating the concept of simultaneous compliance. Veolia recommended to increase ferric chloride dosing, thereby increasing the water's chloride concentration and increasing the CSMR. These recommendations were made to reduce disinfection byproducts, but had the consequence of increasing the potential lead, copper and steel corrosion rates. As discussed at length in my 2020 report, the use of a different coagulant chemical, such as alum, could have helped to address the City's treatment requirements while at the same time reducing the CSMR and the corrosivity of the Flint River water.

**LAN's Failure to Provide Simultaneous Compliance**

LAN's expert Ramaley claims that "…LAN's original recommendation for full lime/soda softening and phosphate addition would have allowed for [Optimal Corrosion Control Treatment] and simultaneous compliance…" (Ramaley 2021, p. 10). As discussed at length both in the previous section of this appendix, the Ramaley Appendix, and my original 2020 report, LAN did not recommend, nor did they implement, proper modern corrosion control. LAN's recommendation for lime-soda softening is not an adequate corrosion control technique and would not have been recommended by any competent corrosion engineer.

Suggesting that LAN's guidance would have resulted in a system that simultaneously met all the water quality parameters is obviously off-base and wrong. This suggestion is totally disproved by the water quality data demonstrated in the City of Flint during the Flint Water Crisis. While LAN provided technical expertise for the City of Flint, the water treatment plant failed to meet its disinfection byproduct requirements, had bacterial and legionella outbreaks (boil water notice), experienced extensive corrosion, and lead was released into the taps of the residents (violating both primary and secondary MCL mandated

requirements). The evidence from Flint speaks for itself and the evidence simply does not support that LAN met the requirements of simultaneous compliance based on their work with the treated Flint River water and Flint Water Treatment Plant.

**Conclusions on Simultaneous Compliance**

The need for simultaneous compliance does not support LAN's or Veolia's actions. LAN and Veolia in fact ignored the requirements for simultaneous compliance by prioritizing one aspect over another (e.g., disinfection byproducts over lead compliance). The end result was corrosive water being distributed throughout Flint. That water damaged pipes and released lead into the residents' drinking water taps. The arguments made by the Defense Experts fail to establish that simultaneous compliance was met. Their arguments also do not undermine or successfully rebut the opinions presented in my 2020 expert report.

# 6 Dr. Edwards's Sewage Sludge Studies

Dr. Marc Edwards's research team at Virginia Tech published two papers utilizing the lead and other heavy metals content of the City's sewage sludge data (referred to as biosolids in their reports). The digested sewage sludge are the solids that are removed from the wastewater treatment plant by gravity settling prior to further treatment and disposal. The referenced papers attempt to use heavy metals concentrations captured in the sewage sludge to understand the Flint Water Crisis. Unfortunately, these papers missed a critical aspect of the transport of lead in the sewer system, and as a result, the model and any conclusions drawn from the model are wrong and cannot be used to interpret the Flint Water Crisis. Similarly, the model cannot be used to evaluate improvements resulting from the implementation of improved corrosion control and/or lead lateral removal. A thorough analysis of these studies and the misapplications in the Defense Expert Reports is presented in Sewage Sludge Appendix. The following presents a brief overview of how the Defense Experts relied upon this flawed analysis, thereby undermining their conclusions and opinions.

The two papers at issue are Roy and Edwards 2020 and Roy, Tang and Edwards, 2019.

The Expert Reports of Duquette, Gagnon, and Finley[1] rely on these two papers. The technical faults of these Edwards papers are discussed at length in the Edwards Appendix of this report. Both Duquette and Gagnon are either unfamiliar with the behavior of sewer systems with both storm water and sewage, or they intentionally choose to ignore those facts in an attempt to obscure the real issues at hand. Two of the central points made by Duquette and Gagnon, based on the faulty data and modeling effort by Edwards's Team, are:

1) *Edwards' [sewage sludge] data show that the switch from Lake Huron water to the Flint River water had no effect on the corrosion behavior of Flint's [lead service laterals] (Duquette 2021, p.18)*
2) *The biosolids work conducted by Dr. Edwards' team revealed that lead concentrations were comparable in 2011 and 2014. This finding speaks to the legacy challenge that lead service lines posed in Flint. (Gagnon 2021, p. 6)*

Both of these analyses and conclusions are wrong. As discussed in the Sewage Sludge Appendix, the modeling analysis ignored the role and impact of wet weather on the flushing of solids containing accumulated lead from the sewers. The Spring of 2011, well before the Flint Water Crisis, was the wettest in Flint's history. The high lead levels and high sludge volume measured do not reflect failed DSWD water treatment, failed Flint wastewater treatment, or other "legacy challenges." They reflect an artifact of the analysis which was overlooked by the Edwards Team. Edwards's Team utilized an incorrect conceptual understanding of the design and operation of the Flint sewerage and storm water systems that ultimately impacted their model. Duquette and Gagnon relied upon this flawed data and modeling efforts, thereby drawing incorrect conclusions without proper support.

In summary, Roy, Tang, and Edwards 2019 and Roy and Edwards 2020 had critical flaws in their analysis and in their understanding of the sewage collection system in Flint. Consequently, their conclusions regarding resulting water lead levels (WLL) cannot be relied upon. Further, any suggestion that data from 2011 and 2014 are similar, and thereby suggesting that the Flint Water Crisis never happened, is wrong.

[1] I mention Dr. Finley only because he noted that he relied on the Edwards' papers in his deposition. I do not otherwise focus on Dr. Finley's analysis in this rebuttal report.

Duquette and Gagnon cannot assume that the lead levels in Flint drinking water in 2011 (while on DWSD water) and in 2014 (during the Flint Water Crisis) were similar based on the elevated sludge lead concentrations.

Similarly, Professors Duquette's and Gagnon's conclusions based on these papers are off-base. These papers cannot be relied upon to suggest that LAN and Veolia properly handled the issues of corrosion control in Flint. The conclusions of Duquette and Gagnon are totally incorrect and the sewage sludge data cannot be used to show that there was a lead water quality issue in the City of Flint in 2011 or be used to interpret the Flint Water Crisis lead levels.

**Appendix 2:**
**Analysis of Ramaley Reports**

# 1 Introduction

This appendix addresses the reports presented by Mr. Ramaley on behalf of LAN. These reports are respectively titled: *Expert Report of Brian L. Ramaley, P.E.: November 25, 2020* and *Supplemental Report of Brian L. Ramaley, P.E.: January 7, 2021*. Mr. Ramaley's Expert Report focuses solely on the work performed by LAN in Flint during 2013-2015, and addresses aspects of worked performed several years before 2013. The rebuttal report responds to the expert reports of Dr. Gardoni and Dr. Russell.

Mr. Ramaley argues that LAN provided sound guidance in Flint and that they had no role in the Flint Water Crisis. This position is wrong. LAN was the water quality advisor that oversaw the commissioning of the Flint Water Treatment plant, and they played a central role in that process. Mr. Ramaley attempts to distract and blame others for the Flint Water Crisis. He does so with an expert report which implements confusing organization and misleading use of testimony. Mr. Ramaley fails to support his positions by utilizing any of LAN's actual work product or written memorialization of LAN's positions, particularly regarding corrosion control.

In the *Supplemental Report*, Mr. Ramaley attempts to rebut the opinions presented in the Russell 2020 report. Mr. Ramaley generally presents opposition to my expert report with inaccurate information and unsupported claims. Mr. Ramaley fails to contest any of the classwide similarities which were a focus of my evaluation in my expert report. Critically, he does not rebut the fundamental fact that the corrosive Flint River water was distributed to all businesses and residents, caused elevated levels of lead in the drinking water in the majority of homes, and damaged piping systems throughout the City of Flint.

# 2 Analysis of the Ramaley Expert Report

## 2.1 Organization

This section presents a general overview of the arguments made by Mr. Ramaley in his expert and rebuttal reports and why they are incorrect. These arguments are structured following the four *Statements of Opinions and Conclusions* in the Ramaley expert report. A subsection for each opinion/conclusion from the report is provided below.

Mr. Ramaley central arguments are:

- *LAN's contractual scope began broadly defined but quickly narrowed;*
- *No "Water Advisor" role was ever described, assigned or allowed to be filled by LAN;*
- *LAN violated no standards of ethics or contractual obligations in the performance of LAN's work related to the [Flint Water Treatment Plant], especially as it relates to corrosion control and public health protection; and*
- *LAN met the standard of care applicable in its work.*

## 2.2 LAN's contractual scope began broadly defined but quickly narrowed;

Mr. Ramaley argues that LAN initially had a broad scope and that scope was reduced. In his conclusions section, Mr. Ramaley fails to make a coherent argument as to what impact the scope reduction had on LAN's role in Flint, and consequently LAN's role in the Flint Water Crisis. While much of his argument is based on witness testimony, he does address some aspects of the contract scope. As will be discussed briefly below, the claims made by Mr. Ramaley related to scope reduction are not supported by the evidence he provides. He states that (Ramaley 2020 p. 23):

*…LAN staff were authorized to provide services on those tasks specifically enumerated in the original contract (Tasks 1 and 2) and the services spelled out in Change Orders 2, 3, 4 and 5…*

*LAN's contract included no responsibility for water treatment processes or finished water quality…*

While Mr. Ramaley argues that LAN had a small role and their contract did not include water treatment processes or finished water quality, the written contract scope does not support that position. The scope states that it would include tasks such as [redacted]):

[redacted]

[redacted]

- [redacted]

The parameters listed above demonstrate responsibility for water treatment processes and finished water quality. Defining water quality parameter goals, design requirements, and treatment requirements established LAN's role as both the technical advisor and *water advisor*. These task items are by definition designing *water treatment process* to meet *finished water quality* requirements. The inclusion of these items in the scope directly opposes Mr. Ramaley statements regarding "no responsibility" for water treatment processes or quality.

Regarding the change orders, I have evaluated Change Order #2 regarding its role in "scope reduction." [redacted]. Mr. Ramaley fails to explain the how these change orders reduced the scope in his conclusions section. However, he does address Change Order #2 in the body of his report. Mr. Ramaley claims that Change Order #2 reduced LAN's scope to six items. The written language of the change order does not match Mr. Ramaley's claim. The Change Order states [redacted]

[redacted]

The signed agreement presents no additional details on the scope (CoF 0072812-CoF0072816).

Mr. Ramaley references his excerpt 204, which includes testimony from Mr. Green to support that the scope was narrowed by Change Order #2. The testimony of Mr. Green presented does not support the position that Change Order #2 removed LAN's responsibility for water treatment processes and finished water quality. Mr. Ramaley relies on Mr. Green's notes recollecting from a meeting in Flint argue that the scope was reduced, but Mr. Green and Mr. Ramaley do not actually address the language written in the Change Order. A proposed scope detailing some tasks has been produced ([redacted]), but this document provides no language negating the original contract requirements regarding water quality, does not state that LAN no longer had this role therefore no longer needed to meet these obligations.

In further support of his position, Mr. Ramaley relies on testimony from Flint's Mr. Johnson. A subset of referenced testimony quoted states (Excerpt 28, Ramaley 2020, p. 40):

*[Question] Okay. And Change Order 2 represented the actual scope of what LAN was contracted to do, correct?*

*[Mr. Johnson, Answer] I'd want to see Change Order 2, but that sounds right, yes.*

*[Question] And as far as the scope that LAN was ultimately charged with, the scope that ultimately made it into Change Order Number 2, that did not include any responsibility for the evaluation of finished water quality coming out of the Flint Water Treatment Plant either with the Flint River water or subsequently with KWA, correct?*

*[Mr. Johnson, Answer]* ***They needed to get our plant to a place where it could produce safe drinking water***.

The testimony referenced by Mr. Ramaley indicates that LAN's scope was not reduced to the point of removing the responsibility for water quality, nor had it been reduced to remove the *water advisor* role, as discussed in the following subsection.

The arguments made by Mr. Ramaley are in large part unsupported by the text of his reports nor the referenced testimony.

LAN was the only engineering design firm and technical expert assisting the City of Flint with the commissioning of the Flint Water Treatment Plant, and remained as a technical adviser throughout the Flint Water Crisis. Mr. Ramaley makes no convincing argument to explain how the LAN scope so as to remove these roles.

[redacted] While LAN appeared to focus on the important task of forcing the water to flow through the plant hydraulically, the process of defining the basis of design is far more complex than simply ensuring that the water flows through the plant. This task means that LAN was charged with showing a thorough knowledge of water quality management and the methodology to accomplish that task. Although not addressed as part of this scope discussion, a thorough evaluation and design of a corrosion control injection system would be the minimum output from this task.

## 2.3 No "Water Advisor" role was ever described, assigned, or allowed to be filled by LAN

The *Water Treatment Advisor*, or *Water Advisor*, title is used in my expert report is used to describe the role of the engineer providing technical expertise to a water system. This concept is well established in the engineering consulting industry. The *water treatment advisor* must consider the various aspects of the treatment system, the water quality, and the regulatory requirements. As discussed in both my 2020 expert report and below, LAN clearly understood the role of the *water advisor* and assumed that role when they initiated their work in 2013. Mr. Ramaley argues that the *water advisor* role never applied to LAN. As demonstrated below, the contractual documents, and the testimony by LAN's Mr. Green, establish that Mr. Ramaley is incorrect.

Mr. Ramaley position is that LAN had no role as the "Water Advisor," as that role was never described, assigned, or allowed to be filled by LAN. Mr. Ramaley's conclusion section that addresses this topic repeatedly offers every reason for how others, but not LAN, filled the role of the water quality advisor. Mr. Ramaley suggests that the design criteria and calculations were provided by MDEQ and the City of Flint made all the decisions regarding the water treatment. However, Mr. Ramaley fails to explain what the role of a *water advisor* is; fails to evaluate what LAN's contractual obligations were with regards to this role; and ignores testimony from LAN's engineers that in fact established both their understanding and assumption of the *water advisor* role. In an attempt to support his position, Mr. Ramaley primarily relies on witness testimony taken six years after the fact, but fails to evaluate LAN's work product or the written memorialized documents, such as the contractual scope and Change Orders.

[redacted]. These tasks are clearly included in the role of the *water advisor*, as this role is understood in the industry. The *water advisor* provides the technical oversite for the treatment system to ensure that design and regulatory requirements are being met. LAN was in fact hired to provide engineering and technical skills that the City lacked. These skills were needed to bring the Flint Water Treatment Plant into service. [redacted] These are the tasks that could only be addressed by the water advisor to the City of Flint, and LAN signed the contract to fulfill the City's water quality advising needs.

Regarding LAN's role as Water Advisor, Mr. Ramaley simply states that LAN was not *a water advisor* because, other than being asked their opinion on possible costs, they were not asked to advise the City on the switch over to the Flint River. However, LAN personnel have been involved with the City since 1997, and it is unlikely that Mr. Ramaley analyzed the entirety of the relationship of LAN to the City of Flint over a 15-year period. He provides no direct source for these statements other than abstract references to deposition testimony that is not explained in the context of his statements.

The determination of the water treatment processes and treatment parameters is the definition of acting in the role of a Water Advisor to the City of Flint. Examples of this role were clearly defined in the original contract scope, as discussed earlier in this section. LAN was tasked with determining the precise elements of the water treatment process, and thereby defining the water-quality fate of the City of Flint. Mr. Green's testimony confirmed that LAN acknowledged that they were the water treatment advisor to the City of Flint in 2013 (Green 2020, Vol 3 p. 598:15-18),:

*[Question]: You testified on Thursday and Friday that at one point, you understood you were the water treatment advisor to the City of Flint in 2013, correct?*

*[Answer by Mr. Green]: Yes.*

*[Question]: Okay. Was that true testimony?*

*[Answer by Mr. Green]: Yes.*

Based on testimony of LAN's own staff, they clearly understood the role of the *water advisor* and understood that they had assumed that role in Flint.

Mr. Ramaley's rebuttal report claims that the contract Change Orders indicated that "the City, working with MDEQ, took on all other aspects of the project including any impacts of using Flint River water on the distribution system" (Ramaley 2021, p. 12). This position is not supported by the written Change Order language, and Mr. Ramaley primarily offers "testimony from numerous individuals [confirming] this to the be case" (Ramaley 2021, p. 12) as his basis to counter this opinion. He offers no documentation to support his supposition that this task was removed from LAN's scope. Mr. Green's own testimony clearly contradicts this position as he believed that the execution of the LAN/Flint contract initiated their role as a water treatment advisor (Green 2020, Vol 3 p. 599:29). While Mr. Ramaley argues that LAN's scope was reduced, he fails to provide a convincing argument that LAN had no role or responsibility for the water quality in Flint and provides no written documents memorialize the abdication of LAN's role as the water treatment advisor. In fact, Mr. Green's testimony confirmed that no emails, memos, or language in the Change Orders exist stating that LAN was no longer serving as the water advisor.

Mr. Ramaley's position that LAN had no role as the water quality advisor are not supported and he fails to rebut my opinions regarding LAN's role in Flint.

## 2.4 LAN violated no standards of ethics or contractual obligations in the performance of LAN's work related to the [Flint Water Treatment Plant], especially as it relates to corrosion control and public health protection

Mr. Ramaley presents the opinion that LAN met the standard of care and their contractual obligations in their work in Flint. In the justification presented for this opinion, Mr. Ramaley elaborates on the history of events in Flint, and repeatedly references testimony regarding those events. However, Mr. Ramaley fails to establish what LAN's contractual obligations were, and if they met them. Further, Mr. Ramaley does not present an explanation of how LAN met ethical or

contractual obligations related to public health protection. The contractual scope has been discussed previously and will not be further addressed here.

Mr. Ramaley's arguments for LAN having met the ethical requirements in Flint rely on two primary concepts. The first is that LAN had no role regarding water quality in Flint. The second is that LAN had no obligation to inform others about the potential corrosion issues, as there is no standard of care requirement for this, and moreover LAN was not aware of the issues. LAN's role as a water advisor is discussed elsewhere and will not be repeated here. They had a role in the water quality in Flint, and they failed to meet the standard of care as presented in my 2020 expert report. Moving on, Mr. Ramaley's opinion on "whistle-blowing" regarding the corrosion issues in Flint is that there are no ethical requirements for this. It is my opinion that LAN had a professional obligation to report the problems and require that it be addressed either by their work or by another consultant (as discussed in Section of 8 of my expert report). I am not aware of written memorialization of this ever occurring. As discussed in Dr. Gardoni's Expert Report, engineers must hold paramount the safety, health, and welfare of the public. LAN failed to do this, either through their lack of awareness of the issues, or by their choice to not address them.

As detailed in my expert report and rebuttal report, it is my opinion that LAN did not meet the standard of care. LAN was the technical advisor to the city, yet they failed to provide the required expertise to manage corrosion.

When LAN signed the contract in 2013, LAN staff were the only engineers working for Flint that had a background in water treatment (Green 2020, Vol 3, pp.708:13-709:5). During this time, LAN failed to identify the existence of highly corrosive water from the Flint River, which was ultimately distributed throughout Flint, even though LAN designed a major overhaul of the Flint Water treatment plant.

Mr. Ramaley argues that LAN did in fact recommend corrosion control (including "phosphate-based" inhibitors), and that the City and MDEQ prevented these recommendations from being implemented. The evidence that LAN recommended phosphate-based inhibitors is very limited and relies on a singular line item in the appendix of a LAN report, which shows a cost for a phosphate system (Ramaley 2021, p.10). I have reviewed no evidence that LAN evaluated corrosion, nor that they produced a modern and adequate corrosion control method (as discussed in the Lawler and Katz Appendix). Mr. Ramaley claims that "LAN personnel did recommend to both the City and MDEQ…that corrosion control be considered more seriously through the inclusion of phosphates, full lime softening, operating at a high pH to achieve stability, and… initial plant testing" (Ramaley 2021, p. 18). Here Ramaley argues that LAN had a "limited role" excluding corrosion and water quality, but somehow was still evaluating corrosion and presenting positions on it to the City and the regulators. This position conflicts with Mr. Ramaley's claim that LAN had no role as the *water advisor* as he suggests they provided

guidance on the treatment processes and corrosion control. Yet, no written documents provide clear evidence that LAN did corrosion control evaluations, nor that they pushed for corrosion control, calling LAN's activities in this regard into question. LAN had a professional obligation to evaluate and address corrosion, and the documentation that I have reviewed do not demonstrate that LAN met that obligation.

LAN created a risk to human health and property by failing to insist that a corrosion control evaluation be performed prior to the switch. The work performed in the early 1990s in nearby Detroit provides a clear model for what LAN could have done in Flint, but did not. As documented in the Reiber et al. 1997 report, DWSD performed a comprehensive corrosion evaluation and ultimately implemented orthophosphate-based corrosion control beginning in the mid-1990s.  LAN's failures in this area are evidenced by the treatment plant going into service without any corrosion control program or corrosion related treatment equipment (such as an orthophosphate dosing system). LAN failed to recommend adequate or modern corrosion control, as evidenced by both the testimony of Mr. Green and EPA's Mr. Schock. Together these failures to require a corrosion control evaluation combined with the failure to recommend adequate corrosion control are the basis of LAN's failure to meet the standard of care.

Mr. Ramaley suggests that LAN met their ethical obligations because they were more protective of the public health than others including City officials and regulators. He states (Ramaley 2020, p. 26):

*All of LAN's unheeded recommendations would have protected public health to a greater degree that what MDEQ required and the City implemented.*

The actions of MDEQ and the City do not establish that LAN met the ethical requirements of engineers. And again, even LAN's supposedly unheeded recommendations—such as full lime-soda softening—were inadequate and would not have provided modern corrosion control capable of protecting human health and property.

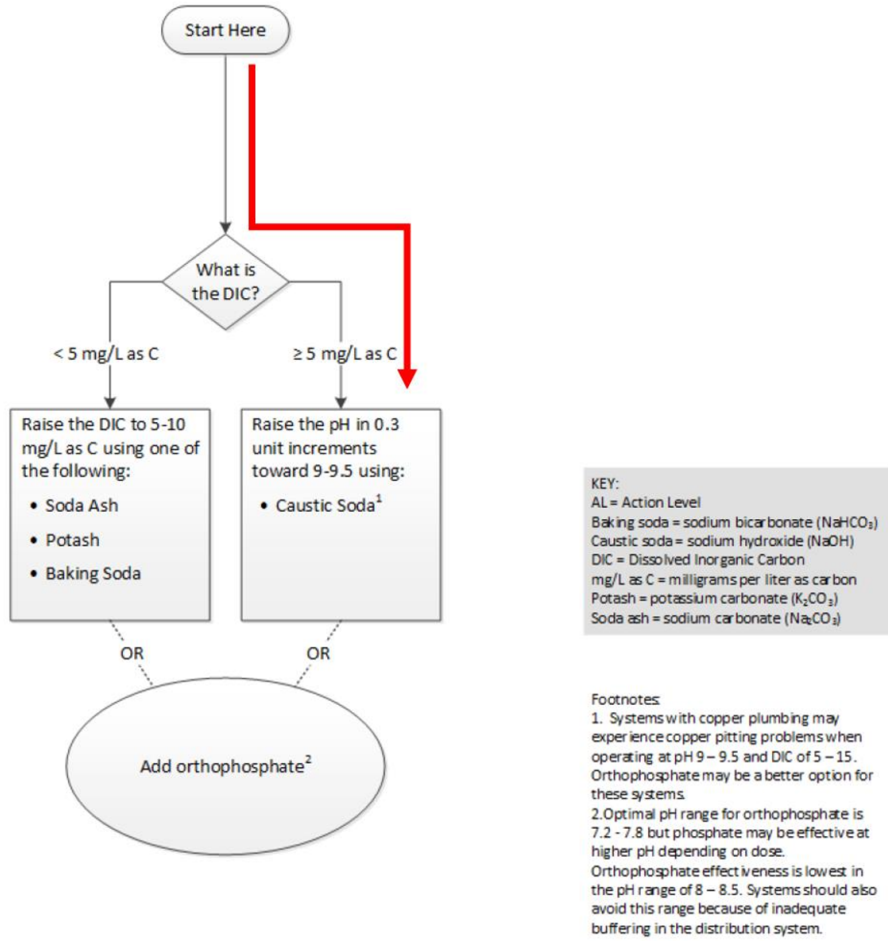
LAN failed to identify the existence of highly corrosive water from the Flint River and ultimately in the distribution system. LAN created a risk to human health and property by failing to insist that a corrosion control evaluation be performed. LAN failed to recommend adequate or modern corrosion control. These failures are the basis of LAN's failure of the to meet the standard of care and their ethical obligation to protect human health. Mr. Ramaley's position that LAN met the ethical and contractual requirements are not supported by the information provided in his report and he does not effectively rebut my positions on this subject.

## 2.5 LAN met the standard of care applicable to its work

LAN failed to meet their standard of care. Mr. Ramaley's claims that LAN met the standard of care are wrong. Mr. Ramaley addressed a variety of topics related to LAN and their standard of care obligations. Regarding standard of care, Mr. Ramaley makes a statement on the topic such as, *"…I conclude that LAN met their standard of care in public health to a degree that no one else involved at the City, MDEQ, and perhaps at EPA, did."* The actions of MDEQ, the City of Flint, and the EPA are irrelevant in this matter, and in any case their actions do not establish that LAN met the standard of care.

LAN failed to provide proper corrosion control because they relied on outdated information and technology. An example of their failure to implement modern corrosion control technology is shown by the following decision Flowchart from the EPA OCCT manual (these failures are discussed at length in the Lawler and Katz Appendix). This tool from the EPA Optimal Corrosion Control Treatment manual clearly shows that, with the water quality predicted for the Flint water (pH 8.8 and DIC = 7 mg/l), corrosion control was required which included either the addition of caustic soda (to raise the pH above 9) or treatment with orthophosphates. It does not support that lime-softening had a role in corrosion control (and softening is in fact described as being ineffective at corrosion control in this manual). This information was available in the literature in various forms long before 2013 when LAN provided the services of *Water Quality Advisor* to the City of Flint. LAN failed to provide either an accurate or successful water treatment program that was needed by the City of Flint.

**Flowchart 1c: Selecting Treatment for Lead only or Lead and Copper with pH > 7.8 to 9.5**




Mr. Ramaley attempts to establish that LAN was knowledgeable in the field of corrosion and could have met the standard of care requirements, but they were not allowed to. He states (Ramaley 2020, p. 27):

*In their testimony, LAN personnel laid out what corrosion control testing they would have employed during that test run to select the appropriate corrosion control strategy and demonstrated LAN's competence in the field.*

However, this testimony fails to establish that LAN met the standard of care in Flint. After intently studying the materials produced by LAN, there is no record of the proposed corrosion testing that LAN personnel testified to. Mr. Green testified six years after the Flint Water Crisis that there is no record of LAN's corrosion control recommendations. Presumably if this information existed, Mr. Ramaley would have presented it as support of his opinions. Similarly, the statements by LAN in testimony do not demonstrate their *competence in the field* of corrosion control or that their actual actions met the standard of care. If LAN had addressed corrosion control in their work, there would have been extensive records of that analysis and memorialized written documents presenting their position that additional corrosion control, such

as orthophosphate, was required for the Flint Water Treatment Plant. Lacking this evidence, I have to conclude that LAN did not perform this work.

The following speculative statement illustrates how little Mr. Ramaley knows of the specifics of the situation between LAN and Flint:

*LAN's recommendations for full lime softening and a corrosion control phosphate-based additive from the range of phosphate products available, if implemented, would have likely avoided the problem experienced with corrosion and elevated lead levels that Flint experienced after switching to the Flint River as a source*

Mr. Ramaley provides no evidence that this treatment method provided adequate or modern corrosion control. As discussed in the Lawler and Katz Appendix, this rebuttal report, and my 2020 expert report, the treatment methods proposed by LAN did not provide corrosion control that met the industry standards. This open-ended statement made by Mr. Ramaley years after the fact, claiming that LAN would have recommended an additive from the range of phosphate products available, is simply unbelievable. Once again, where are the documents from LAN's files supporting this statement? Where are the calculations and their written recommendations made to the City and regulators? The answer is that there are no such recommendations and this failure establishes part of the basis of LAN's failure to meet the standard of care.

Mr. Ramaley continues as follows in an attempt present his position that LAN met the standard of care (Ramaley 2020, p. 34):

*Virtually any other engineer that may have been hired by the City to provide the same services on the project, with ordinary learning, judgment and skill under the same or similar circumstances as in this case would have likely followed a similar course of action.*

As discussed briefly above, nearby Detroit provides a model what another engineer would have done to evaluate corrosion. The engineers work in Detroit, approximately 20 years prior understand the needs for corrosion control. They studied the issues, tested the water, developed a corrosion control plan and implemented orthophosphate treatment (Reiber et al. 1997). There was no crisis in Detroit due to the water quality and because DWSD utilized the corrosion control program recommended by their consultants. Therefore, it is not true that "[v]irtually any other engineer…would have followed a similar course." As discussed at length in both my rebuttal report and 2020 expert report, LAN failed to meet the standard of care. They failed to address corrosion and they did not demonstrate "ordinary learning, judgment, and skill" in the work they performed in Flint.

## 2.6 Classwide Issues

Regardless of these other issues with the Ramaley report, Mr. Ramaley offers no rebuttal of the opinions of my 2020 expert report regarding the common aspects of the Flint Water Crisis which tie the Flint business and residents together in a class. The residents of Flint share numerous common/identical conditions including exposure to the same corrosive water, exposure to elevated levels of lead, and widespread damage to the plumbing systems. As an example, Mr. Ramaley makes no reference to the homes or the data collected by the Edwards Team and addresses no specifics about the City of Flint and its water system. He does not rebut my position that plumbing components in homes contain very similar materials and techniques of manufacturing and installation, they all received the same corrosive Flint River water, and they were all manufactured to comply with similar ASTM standards and installed under similar plumbing codes, making the homes and businesses characteristic of a Class. Mr. Ramaley's failure to show that LAN met the standard of care is only further support of the characterization of the residences and businesses as members of a class.

# 3 Conclusion

Mr. Ramaley argues that LAN provided sound guidance in Flint and that they had no role in the Flint Water Crisis. This position is wrong. LAN was the technical advisor that oversaw the upgrade, redesign, and commissioning of the Flint Water Treatment plant and they played a central role in that process. Mr. Ramaley attempts to distract the reader with issues that are irrelevant, and instead blames others for the Flint Water Crisis when in fact a large part of the responsibility lies solely with LAN.

Mr. Ramaley fails to support his position utilizing any of LAN's actual work product or written memorialization's of LAN's positions, particularly regarding corrosion control. Instead, he relies mainly on testimony, suggesting that LAN's work product doesn't exist to support his positions.

In the *Supplemental Report* Mr. Ramaley attempts to rebut the opinions presented in the Russell 2020 report. He generally presents opposition to these reports based on inaccurate information and with unsupported claims. Mr. Ramaley fails to contest any of the class wide similarities. These classwide similarities were a focus of my 2020 expert report. Examples of these wide-spread common issues include: (1) corrosive water was distributed to all businesses and residents; (2) that water caused elevated levels of lead in the drinking water throughout Flint; and (3) the corrosive water damaged plumbing systems throughout Flint.

**Appendix 3:**

**Analysis of Lawler and Katz Reports**

# 1 Introduction

This Appendix addresses the reports prepared by Professors Lawler and Katz on behalf of Lockwood, Andrews, and Newnam (LAN). The first is the Expert Report dated November 25, 2020, and second is the Expert Report dated January 7, 2021.

In the introduction to their report, Professors Lawler and Katz state that they were tasked with evaluating *allegations that personnel at the engineering company Lockwood, Andrews and Newnam (LAN) failed to meet the Standard of Care in their work related to the Flint Water Treatment Plant in the time frame 2011-2014* (Lawler and Katz 2020, Ex. 8, p 20). The professors fail to define what the standard of care is; they fail to provide a clear explanation regarding if LAN met their standard of care in their opinions; and in fact they never again mention standard of care in their report.

Lawler and Katz's reports can be distilled into three opinions:

(1) LAN's recommendation of lime-soda softening was a good suggestion;

(2) Corrosion is impossible to predict; and

(3) Engineers in 2013-2014 would not have been expected to understand or use CSMR.

All three opinions are easily rebutted. As will be discussed below, first, LAN failed to meet the standard of care. Second, their recommendations for lime-soda softening were not good, did not provide adequate corrosion control, and were not in-step with the thinking of water treatment technology in 2013. Third, their position that corrosion cannot be predicted, or tested, is incorrect.

Corrosion indices provide critical tools to determine if the water will tend to be corrosive, and testing can be performed to confirm both the corrosive nature of the water and the effectiveness of various corrosion control methods. Their position that CSMR was not established in 2013-2014 is incorrect; the concept of CSMR has been around since the 1980s, and was well established in 2013. Calculating CSMR, and other corrosion indices, would have provided the engineers for LAN a critical tool for evaluating the corrosive tendency of the water (Masten et al. 2016).

Professors Lawler and Katz present the position that if the City had only followed the LAN recommendations to implement full lime-soda softening, then the water quality problems experienced during the Flint Water Crisis would never have occurred. I do not agree with this position, and this issue is discussed at length in my 2020 expert report and in brief below. My

2020 report presents a discussion of the activities and failures of LAN to meet their Standard of Care during the conduct of their work in Flint.

In contrast, the reports by Professors Lawler and Katz offer no substantive opinions that spread light on, or make any meaningful input to, how the problems that caused the Flint Water Crisis could have been avoided by following the LAN recommendations.

Finally, two of the primary purposes of my 2020 expert report were to evaluate the evidence of harm to the plumbing systems throughout Flint and to evaluate the common class conditions impacting the businesses and residents throughout Flint. Professors Lawler and Katz do not contest that the corrosive water was supplied throughout all of Flint; they do not contest that there was damage to plumbing systems throughout Flint; and they do not contest that there are common impacts and damages caused to the members of the class.

# 2 Analysis of Lawler and Katz Reports

The following subsections address the three opinions synthesized from the Lawler and Katz reports:

(1) LAN's recommendation of lime-soda softening was a good suggestion;

(2) Corrosion is impossible to predict; and

(3) Engineers in 2013-2014 would not have been expected to understand or use CSMR.

## 2.1 Response to (1) LAN's recommendation of lime-soda softening was a good suggestion;

The Professors' core argument is that LAN's recommendation of lime-soda softening as a primary means of corrosion control would, in their opinion, *"…fit within the guidelines for corrosion control that represented the state of knowledge at the time…"* (Lawler and Katz 2020, PageID. 53678).

That opinion is wrong. In fact, as stated by Lawler and Katz in their 2021 report, *"…softening is not generally considered a primary means of corrosion control…"* (Lawler and Katz 2021, p.7). Lawler and Katz fail to support that LAN's recommendations met the standard of care. As explained below, the addition of lime for water softening has never been, and will never be, a suitable drinking water corrosion control technique (OCCT 2016), and accordingly LAN did not meet their standard of care with this recommendation.

In their first report, Professors Lawler and Katz provide a lengthy academic dissertation on the chemistry of water softening with the lime process, and on conventional water treatment. However, they fail to mention both that water softening is conducted primarily for aesthetic reasons, and that no practicing corrosion control engineer would ever recommend lime-soda softening as a suitable form of corrosion control.

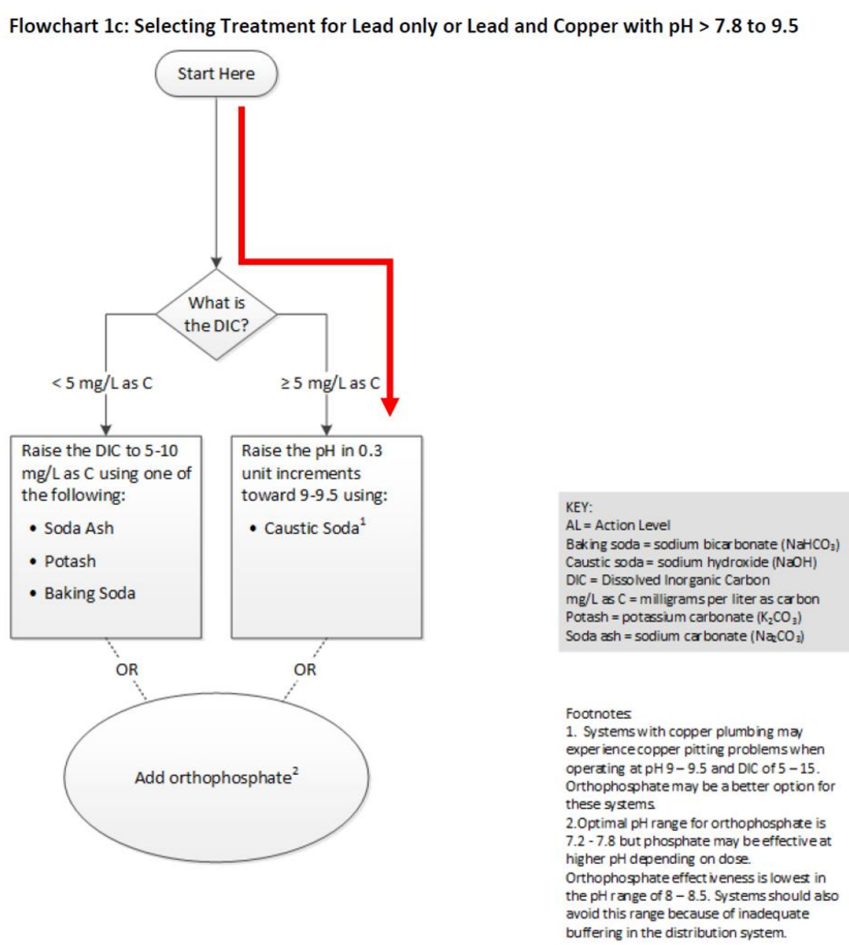
Lime-soda softening is not an acceptable method to prevent either lead dissolution or to form protective pipe scales. In contrast, orthophosphate is known and well established to form a protective scale and is commonly used as a corrosion control method. Moreover, Professors Lawler and Katz fail to provide any references that state that lime-soda treatment is a corrosion control treatment strategy and there are many references that state the opposite (e.g., EPA OCCT 2016).

The EPA's Michael Schock evaluated the performance of a variety of treatment alternatives for the control of lead solubility, dating back to 1989. The consultants for the City of Detroit DWSD in 1992 realized that the addition of orthophosphate is critical to implementing optimal corrosion control (OCCT) as required by the EPA Lead and Copper Rule (1991). Lime-soda treatment is not listed as one of the alternatives by Mr. Schock, although orthophosphate addition is. There is a reference to operating a water treatment system to produce a uniform calcium carbonate scale,

but Schock dismisses this alternative based on his evaluation of the feasibility/practicality of doing such.

As further evidence of their flawed reasoning, Professors Lawler and Katz base their opinion in part on the information provided in the USEPA Optimal Corrosion Control Treatment (OCCT) guidance manual. This document provides a series of flowchart-style decision trees for evaluating appropriate corrosion control options. The Professors argue that the appropriate decision tree is Flowchart 1C for the Flint River water produced by the FWTP. Professors Lawler and Katz recommend that the DIC be lowered to 7 mg/l with a pH of 8.8, which directs one to the right-hand options in this flow chart (See Figure A3-2.1.1, red arrow). As can be seen, the OCCT guidance recommendations indicate that the solution is **either** to raise the pH with caustic soda to 9-9.5 **or** to add orthophosphate without increasing the pH or perhaps to lower the pH to 7.2 to 7.8 to improve the performance of orthophosphate. There are no other recommendations from the OCCT. But LAN recommended neither of those recommendations.

*Figure A3-2.1.1: Flowchart 1C reproduced from the USEPA Optimal Corrosion Control Treatment guidance manual (USEPA OCCT 2016). The red arrow indicates that appropriate evaluation for the Flint River water.*



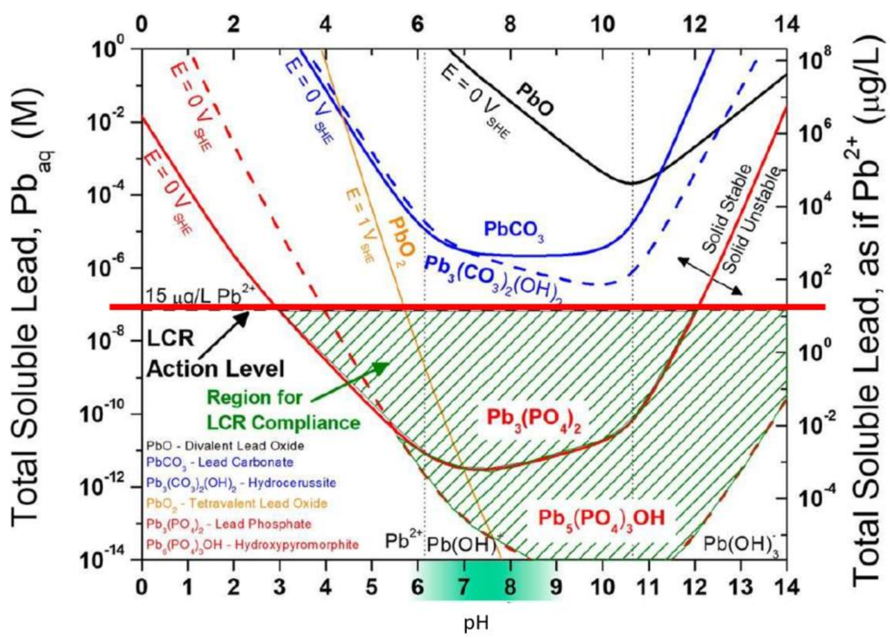
The results in Flint speak for themselves; if modern corrosion control as proposed in the OCCT Flowchart 1C had been implemented, the Flint Water Crisis could have been avoided.

Professor Lawler and Katz also rely on a paper by Tully et al. 2018 to establish that softening is used as corrosion control at two plants located in the Midwest. The Tully et al. paper evaluated 22 midwestern water systems to review how well mathematical models of water chemistry compared with observations of the chemical formulation of pipe scales. Tully et al. was not aimed at evaluating the effectiveness of corrosion control and does not establish that softening was an appropriate corrosion control method in Flint.

Lawler and Katz claim treatment plants with softening were "*predicted (by chemical equilibrium modeling) to have two of the lowest lead solubility values of the 22 plants investigated" (Lawler and Katz 2021, PageID 53653).* The Tully et al. paper evaluated a mathematical model of lead scales and chemistry, and found that the model performed poorly at predicting actual lead scale formation (which was the purpose of the paper; their models worked in less than half of the systems evaluated). Additionally, these modeling efforts to predict scale chemistry and formation were performed with water qualities that are different than the Flint River water and are therefore irrelevant. The Tully et al. paper does not establish softening as an appropriate corrosion control method in the industry, nor does it justify that it was an appropriate method in Flint.

In addition, the study by Santucci and Scully 2020 demonstrates, that based on thermodynamic equilibrium, that the likely phosphate scales, are far more insoluble than any lead carbonate scale that would be developed following the lime-soda softening, thereby providing better corrosion control. The Santucci and Scully conclusions directly oppose the opinion presented by Professors Lawler and Katz that the LAN proposed treatment strategy, utilizing lime-soda softening would be effective in Flint. The Santucci and Scully paper found that successful and continuous control of lead below the EPA lead Action Level of 15 ppb, requires that orthophosphate be added to precipitate lead as demonstrated in Figure A3-2.1.2 below, which is reproduced from their paper. This figure demonstrates that when corrosive waters are present, the only viable method to ensure that the EPA lead action level is met continuously is orthophosphate addition thereby achieving the Optimal Corrosion Control Treatment (OCCT).

*Figure A3-2.1.2: This figure is reproduced from Santucci and Scully 2020. The red horizontal line has been added for emphasis and represents the EPA action level of 15 ppb (µg/L). The horizontal axis shows pH values ranging from 0-14, and the vertical axis shows the water lead concentrations. This figure graphically demonstrates their opinion that in corrosive waters, the only successful lead control strategy for continuous Lead Action Level compliance is orthophosphate. The orthophosphate forms insoluble lead phosphate scales. This finding is demonstrated by the green hatched area on the figure. In this area, lead concentrations are below the Action Level (emphasized with a red line) and precipitates of $Pb_3(PO_4)_2$ and $Pb_5(PO_4)_3OH$ are shown. Their findings fully support that OCCT for lead corrosion control requires orthophosphate additions.*




Santucci and Scully 2020 provide a summary of what the triggers were for lead release during the Flint Water Crisis. None of the items suggest that the softening proposed by LAN could have prevented the Flint Water Crisis. Their list of triggers from their article are described as follows (Santucci and Scully 2020, p. 23211):

*The scientific triggers for the higher lead release were*

*1) very high incidences of lead service lines, lead solder, galvanized iron pipe, and leaded brass in the water distribution system;*

*2) increased water acidity;*

*3) increased chloride to sulfate mass ratio from use of ferric chloride coagulation and the Flint River's natural salinity; and*

*4) a failure to continue orthophosphate water treatment for corrosion control even though it had been successfully used for decades*

Based on these statements by Santucci and Scully and the analysis of the figure above, it is clear that Professors Santucci and Scully would oppose Professor Lawler and Katz's position that LAN made good recommendations regarding lime-soda softening as corrosion control when treating the Flint River water.

Furthermore, Professors Lawler and Katz provide a quote from the US EPA OCCT guidance in an attempt to support their positions regarding softening as a corrosion control method (Lawler and Katz 2020, Ex. 9, p. 28):

*The Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems (OCCT) was last updated in 2016, and still lists pH and alkalinity adjustment among their "available corrosion control treatment methods."*

It must be made clear that a water quality/corrosion expert would not refer to lime-softening as *"pH and alkalinity adjustment,"* as referenced in the EPA OCCT guidelines. The OCCT states the following (EPA OCCT March 2016 report p. 22):

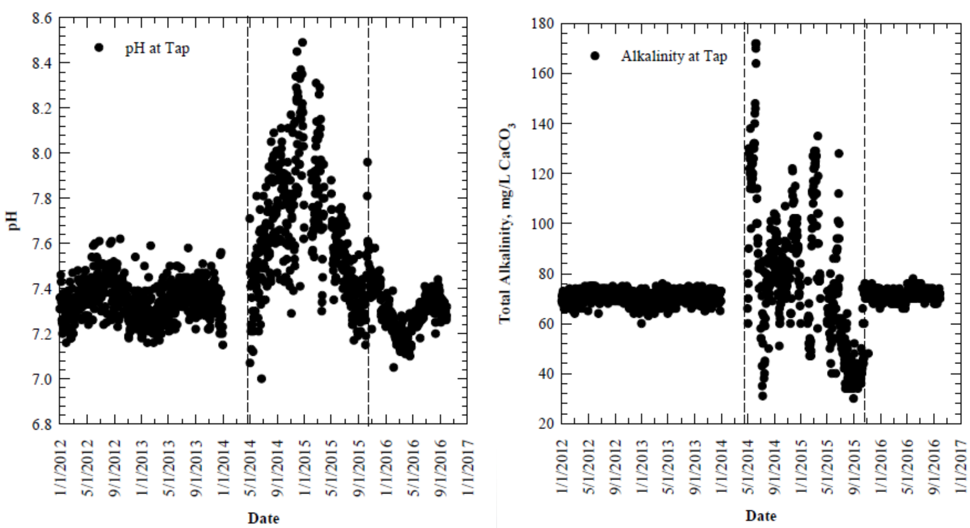
*Calcium hardness adjustment is not discussed in this chapter because newer research has shown that calcium carbonate films only rarely form on lead and copper pipe and are not considered an effective form of corrosion control (Schock and Lytle, 2011; Hill and Cantor, 2011).*

While pH and alkalinity definitely change during lime-soda treatment, the reference in the OCCT is aimed directly at providing treatment by adding chemicals to elevate the pH with or without adding buffer capacity (alkalinity). These changes to pH and alkalinity are specifically accomplished by adding chemicals, such as caustic soda, or by removing carbon dioxide with aeration. As shown above, the OCCT is not suggesting that a process designed to remove calcium and magnesium hardness (lime-soda softening) is acting as a corrosion control strategy (US EPA OCCT 2016, pp. 22-23).

LAN's recommendations with regards to its treatment system failed to achieve a system that could maintain stable water (which is critical for corrosion control). The LAN recommendations included lime-soda as the primary treatment with regards to corrosion, which is by its nature a failure to recommend an adequate corrosion control method that met the state of knowledge at the time (2013-2015).

Professors Lawler and Katz also cannot claim that optimal corrosion control treatment methods were not well established in 2013. Nearby Detroit, for instance, had established Optimal Corrosion Control Treatment beginning with studies done by their water advisory consultants in 1992. Detroit Water and Sewer District (DWSD) fully implemented OCCT —through the addition of orthophosphate—by 1996. The implemented corrosion control strategy was based on pilot scale proof of concept conducted in 1992. Flint had this same modern corrosion control from DWSD up until the switch to the treated Flint River water in 2014. Flint's water stability was ultimately restored in October 2015 when the DWSD water, with an increased orthophosphate treatment, was reintroduced into the Flint water distribution. The impacts on Flint of the corrosive treated Flint River water, as compared to the DWSD water, before, during and after can be seen in the following graphs.

*Figures A3-2.1.3A and A3-2.1.3B: pH (left) and alkalinity (right) of the treated water supplied in Flint from 2012-2017. The vertical dashed lines show the period the system was supplied with Flint River water from approximately May 2014-October 2015. Note the dramatic variability in both parameters during operation on the Flint River water as compared with the DWSD periods (January 2012-May 2014 and October 2015-October 2016). As can be seen in the plot on the right, alkalinity and pH were extremely variable during the Flint Water Crisis and both were uniform when DWSD water was being served in Flint.*




Clearly modern corrosion control methods, such as those used by DWSD, were both available and well established in 2013. Flint's own water system benefitted from those methods both before and after the Flint Water Crisis, when Flint relied on the OCCT DWSD water as their supply.

**Appendix 3:**
**Analysis of Lawler and Katz Reports**

Professors Lawler and Katz conclude their analysis of LAN's work in Flint by determining that water with a final pH of 8.8, alkalinity of 30 ppm, and dissolved inorganic carbon (DIC) of 7 ppm, would be a good result with respect to overall water quality. I concur with this statement. However, these levels were never even remotely achieved by the City of Flint in its water treatment system. This treatment system was designed by LAN and later reviewed by Veolia, although neither addressed the core problems nor did they foresee or cure the corrosion issues.

Professors Lawler and Katz do not actually model the treatment process designed by LAN with lime-softening for this system. As a result, it is unclear what the value of their dissertation is as applied to the real-world conditions in Flint. As shown on Figure A3-2.1.3A. above, the effluent from the lime softening process at Flint suffered very large swings in pH from less than 7 to above 8.5, indicating the total lack of process control and the production of a very unstable and scale-destabilizing water. These conditions occurred in the system for which LAN served as the technical water quality advisor and for which both LAN and Veolia were on-site to assist the City with their water quality problems.

## 2.2 Response to (2) corrosion is impossible to predict;

Referencing Lawler and Katz opinion (2) above, the professors argue that a water source's propensity for corrosion is impossible to predict. However, this is plainly not true. In fact, there is an entire field of literature devoted to developing best practices for corrosion prediction and detection. For example, as presented in my 2020 expert report, indices such as the Langelier Saturation Index, Larson-Skold index and the Chloride Sulfate Mass Ration (CSMR) are well established tools in this field, and have been so since 1936 when Langelier published his seminal paper on corrosion indices titled The Analytical Control of Anti Corrosion Water Treatment.

Moreover, studies performed in the early 1990s in nearby Detroit (the supplier of water to Flint pre- and post-Flint Water Crisis) argue directly against the Professors' position that the LAN design and proposal to incorporate lime-soda softening as a corrosion control alternative was a suitable one. In March of 1992, the City of Detroit (DWSD) embarked upon an evaluation primarily aimed to reduce the impact of their treated water on lead solubility from lead service laterals in their service area which provides water to 4 million people. This work was performed in part due to the requirements by the (then newly) passed 1991 Lead and Copper Rule (LCR).

Reiber et al. 1997 documented this work in Detroit and reported the following:

***In March 1992****, the DWSD began the first phase of its EPA lead and copper corrosion control study, the EPA-mandated desktop study. The desktop study identified three lead corrosion control techniques as potentially capable of reducing lead concentrations in the DWSD: orthophosphates, zinc orthophosphates, and pH adjustment.*

The purpose of the "EPA mandated desktop [corrosion] study" was to predict the impacts of corrosion and to address them by reviewing alternatives that were to be followed by pilot scale studies (note that there is no mention of softening as a corrosion control alternative in the DWSD desktop study). This technique and approach were fully available to LAN as had been demonstrated in Detroit approximately 20 years before than the Flint Water Crisis. Had LAN simply followed the corrosion investigation and control methodology set forth in the 1991 Lead and Copper Rule guidance, and then performed the same activities as those that Detroit did in 1992, the Flint Water Crisis would never have occurred.

As discussed previously, the DWSD corrosion evaluation provides an example of how to evaluate and address the corrosive tendencies of water. Beginning in 1992, DWSD studied the issue and identified that the superior alternative for the Lake Huron water was the addition of orthophosphate. DWDS and their consultants conducted a one-year-long pipe loop test to evaluate the available corrosion control methods in 1992:

Their total weighted ranking (from best to worst corrosion control alternatives) was:

- Orthophosphate
- Zinc orthophosphate
- pH of 8.1
- pH of 8.7

If LAN had followed the path of DWSD and its consultants, Tucker, Young, Jackson and Tull (TYJT), and CH2M Hill, they would have achieved a successful outcome for Flint.

LAN was the technical expert assisting the City of Flint with the commissioning of the Flint Water Treatment Plant, and remained as a technical adviser throughout the Flint Water Crisis. [redacted], yet LAN failed to address corrosion as part their work in Flint.

The use of ferric chloride, as recommended by LAN, is another critical area whereby increased corrosion rates could have been predicted and accounted for, but were not. Lawler and Katz suggest that LAN's recommendations regarding ferric chloride were appropriate, but they fail to account for the fact that the impacts on corrosion needed to be considered and addressed by LAN. LAN recommended that ferric chloride be used in 2013 to treat the water, and recommended increasing the dosing of ferric chloride to assist with disinfection byproduct issues in 2014-2015. LAN should have recognized that increasing the ferric chloride dosage would have the triple negative impacts of increasing the CSMR; increasing the absolute concentration of chloride; and increasing the galvanic corrosion of high-lead brass and leaded solder. The impacts of using ferric chloride on corrosion were, in fact, predictable and should have been accounted for by LAN. On the subject of ferric chloride and its impacts on the corrosion index

CSMR, Professors Lawler and Katz quote from the 2016 EPA OCCT Guidance Manual, which states (emphasis added) (Lawler and Katz 2021, PageID 53652):

*The chloride and sulfate content in water can change with a switch from sulfate-based coagulants (such as aluminum sulfate (alum) and ferric sulfate) to chloride-based coagulants (such as ferric chloride).* ***Conversely, a change from ferric chloride to alum may increase the sulfate content in the water, potentially reducing lead release****.*

Based on this quotation from their report, Professors Lawler and Katz were obviously aware of the issues that related to both the use of ferric chloride and the problems with increasing the dosage of ferric chloride. They were also aware of the advantage of switching to ferric sulfate over ferric chloride as a coagulant with respect to reducing corrosion rates and impacts. LAN could have used these same tools which were available at the time (see discussion of (3) below), and could have predicted that increasing the chlorides with ferric chloride presented a risk of increased corrosion, and that switching to alum or ferric sulfate would have reduced the corrosion rates.

Another example of the predictable nature of corrosion—as it pertains to two critical water quality aspects in Flint—appears in the concluding lessons from a report by Reiber et al. in 1997, titled *A General Framework for Corrosion Control Based on Utility Experience*. For reference, this report is cited by Professors Lawler and Katz. That report lists 18 lessons on corrosion to be learned from the utilities studied. I highlight these two lessons—which reflect common knowledge as of 1997—to emphasize the importance of producing stable water quality and the risks of switching critical water quality parameters (as occurred when the source water was switched to the Flint River). Said another way, failure to account for these critical conditions was well established as leading to potential corrosion. The emphasis below is my own.

Lesson 16: *…* ***pH excursions*** *that drop the distributed pH by greater than 0.5 units, even for brief periods, appear to* ***disrupt the effective passivation of the corrosion surfaces, especially on brass and lead/tin solder surfaces.***

Lesson 17: *The re-equilibration of the corrosion scales during* ***the introduction of a substantially different water quality resulted in the disruption of these corrosion scales, releasing both metallic and organic constituents.***

These two lessons—again, dating back to 1997—highlight critical aspects of the state of knowledge when LAN was working in Flint and the ability to evaluate (predict) when corrosion issues may be present. Specifically, the inability to control pH in the treatment plant presents a major risk for corrosion in the distribution system, as addressed in Lesson 16. LAN needed to provide guidance that resulted in a treatment system capable of achieving a stable pH. Failure to do so was a predictable source of scale destabilization and corrosion.

Regarding Lesson 17: it was well known, in the water treatment industry, that switching water sources, which necessarily result in a "substantially different water quality," can result in scale

destabilization and metals release. LAN was overseeing the switchover from the Lake Huron water to the substantially different Flint River water. This risk of corrosion was predictable, and LAN needed to implement corrosion control evaluations and treatment to mitigate the impacts of this change. Failure to consider these issues resulted in a system that lacked proper corrosion control, caused elevated levels of lead, and damaged piping systems. Again, the corrosive nature of the Flint River water was predictable, and followed the patterns established by other waters systems as demonstrated approximately two decades prior. All of this information is in direct opposition to Professors Lawler and Katz's opinions that corrosion cannot be predicted.

Professors Lawler and Katz finish their response to my 2020 expert report with the following statement (Lawler and Katz 2021, p. 11-12):

*Even today, the understanding of corrosion in water distribution systems has weaknesses, and we are unable to predict when corrosion will or will not occur to a level requiring corrective action.*

This statement tries to lead the reader to believe that we have no tools or engineering expertise available to evaluate corrosion, or the possibility of corrosion in our drinking water supplies. Yet the DWSD consultants in the early 1990s were able to predict the corrosion and design a successful program to address the corrosion of lead service lines in the Detroit distribution system. Clearly, expertise in corrosion control existed in the Flint metro area based on the work performed in nearby Detroit in the 1990s by a Detroit based consultant TYJT remains in business today. The DWSD consultants provided a successful corrosion control plan which was developed and implemented by 1996. LAN failed to evaluate and properly address the corrosion that would be associated with the switch to the treated Flint River water, LAN failed to address the issue once the corrosive water was flowing throughout the city, and LAN failed to solve the Flint River Water Crisis. Clearly, LAN failed to meet their standard of care.

## 2.3 Regarding (3) engineers in 2013-2014 would not have been expected to understand or use CSMR

Regarding argument (3) above, Professors Lawler and Katz make the following statement (Lawler and Katz 2021, Ex. 8 p. 4):

*We acknowledge that a careful reading of the research literature published prior to 2013 specifically about the CSMR would lead to an understanding that this ratio might be a parameter to consider if one were concerned about lead corrosion.*

I agree with Lawler and Katz that CSMR was well established and available to engineers in 2013. This issue was discussed in my 2020 expert report, and is accordingly only touched on briefly here. The concept of Chloride Sulfate Mass Ratio (CSMR) has been a feature of the corrosion-control field since 1983, when Oliphant documented the potential role of this ratio on

galvanic corrosion of high-lead solder and copper pipe fittings. More recently (prior to 2013), CSMR has also been the subject of papers by Marc Edwards in 2007, and the AWWA Research Foundation report by Edwards published in 2010. Moreover, as addressed by Professor Masten in her 2016 paper on Flint, *"…commonly used indexes could have predicted that the treated Flint river water would likely corrode lead pipes…"* (Masten, Davies and McElmurry 2016, p. 31). One of the prime examples of the applicable corrosion indices for Flint, as presented in Masten paper, is CSMR, indicating that the tools were available, known to the industry, and established prior to the Flint Water Crisis in 2013-2014.

The 1996 book, Internal Corrosion of Water Distribution Systems, a joint report by AWWA and DVGW-TEW, clearly addresses the issue of lead corrosion control and the role of chloride and sulfate (p.182-183). The authors noted that research has shown that *"…the lead corrosion mechanism is affected by the presence of chloride in oxygen-poor environments"* and that "*sulfate and chloride… might occasionally be found in water supplies at a sufficiently high level to impact lead solubility"* (AWWA and DVGW-TEW 1996, p. 182). This book was published in 1996 and the principal author of this section was the EPA's Michael Schock, which addressed the issue of chloride accelerated corrosion in a section titled Corrosion and Solubility of Lead in Drinking Water.

In response, the Professors claim that the Flint Water Crisis increased the visibility of CSMR; however, the American Water Works Association (AWWA) had already conducted a major study on CSMR that was performed by Dr. Marc Edwards and published in 2010, years before LAN designed the upgrade to the FWTP. While I agree that the Flint Water Crisis heightened awareness across the industry of lead corrosion problems, I do not agree that *"…LAN or any other environmental engineering firm would have been extremely unlikely to be able to predict that a change in CSMR would, or might, result in a drastic change in lead release in the water system…" (Lawler and Katz 2021, PageID 53652).* As discussed previously, CSMR was established in the industry by the early 2000s, and as was presented in the Reiber et al. 1997 discussion in (2), it was well known that substantial changes in the water quality and water source can disrupt internal scales and cause the release of metals into the drinking water.

Professors Lawler and Katz go on to state the following (Lawler and Katz 2021, p. 7):

*In 2013, a water treatment engineer working for LAN or any other environmental engineering firm would have been extremely unlikely to be able to predict that a change in the CSMR would, or might, result in a drastic change in lead release in a water system.*

I totally disagree with this statement. The work of the consultants in Detroit, TYJT and CH2M Hill (documented in Reiber et al. 1997), provides an example of what another environmental engineering firm would have done faced with the types of issues in Flint. The DWSD consultants completed a comprehensive corrosion evaluation that resulted in the implementation of the DWSD OCCT by 1996. The TYJT study identified the viable alternatives as either pH

adjustment or orthophosphate addition, and then they provided recommendations specifically tailored to the needs of DWSD in 1992. It is obvious that TYJT needed technical assistance on the issue of developing an OCCT and controlling lead corrosion and they retained CH2M Hill to provide that expertise, in the exact same manner as LAN could have done.

Modern corrosion control was well established when the AWWA published a comprehensive report on the state of the art in 1997 and then again in 2010 on CSMR. LAN's lack of awareness on the state of corrosion control knowledge indicates that the LAN engineers were not providing technically sound advice and therefore not meeting their obligatory standard of care. As can be seen by the Flint Water Crisis, results of switching to the Flint River as a water source were significant. This result was easily predictable using technology and methods common in the 1990s, and even more so twenty years later in 2013.

Clearly, the information and engineering approaches needed to make the right decisions and provide Flint with an OCCT program, as required by the Lead and Copper Rule, existed long before 2013.

# 3 Conclusion

As discussed in this report, the positions presented by Lawler and Katz do not establish that LAN met the standard of care with regards to corrosion control in Flint. LAN's recommended treatment method did not provide adequate corrosion control, and they failed to utilize well established methods in the industry to evaluate corrosion tendencies of the Flint River.

As a final matter, Professor Lawler and Katz do not provide any rebuttal to my opinion that high levels of lead were documented in homes across Flint, the majority of which did not contain lead service laterals. Nor do they disagree that all of the houses were exposed to the same highly corrosive treated Flint River water, or that they all shared high levels of lead containing materials in their solder (in the homes with copper plumbing), faucets, and valves. These high-lead content plumbing components were subjected to corrosion by the Flint River water, and these same components continue to be subjected to corrosion today. Therefore, Professor Lawler and Katz's reports, even with their inaccuracies, do not undermine the fact that all homes in Flint were exposed to and damaged by the corrosive Flint River water, and that they share common characteristics of Class.

**Appendix 4:**
**Analysis of William Bellamy Declaration**

# 1 Introduction

This appendix addresses the Declaration of William Bellamy, Ph.D., P.E., BCEE, January 6, 2021 (henceforth Bellamy 2021).

Professor Bellamy presents an analysis of "Veolia North America's (VNA's) professional services while contracted by the City of Flint (CoF) in February and March 2015. Professor Bellamy organized his summary of opinions into the following three subcategories.

1) Veolia's scope-of-services and work product;
2) Veolia's activities related to potential corrosion control and lead; and
3) Veolia's professionalism.

In my opinion, Professor Bellamy's report presents a misleading representation of the events in Flint and of Veolia's roles and responsibilities. Professor Bellamy's central opinions are: Veolia acted professionally, Veolia provided appropriate recommendations regarding lead issues, Veolia met the standard of care, and that Veolia met the scope of work requirements. As was discussed at length in my 2020 expert report, the main body of my rebuttal report, and in this appendix, it is my professional opinion that Veolia failed to meet the standard of care, they provided inadequate and incorrect recommendations regarding lead and corrosion control, and Veolia failed to provide recommendations that could have averted or substantially mitigated much of the harm caused by the Flint Water Crisis.

Professor Bellamy presents extensive discussions on Veolia's scope, professionalism, and the soundness of their recommendations related to topics outside of corrosion control (such as, disinfection byproducts). While I disagree with many of the positions taken by Professor Bellamy's regarding Veolia's actions in Flint, I focus this analysis instead on what I understand to be the actual scope of Veolia's obligations (as defined by the contracting documents and the work Veolia actually performed in identifying and making recommendations for water quality and corrosion control issues in Flint),[1] Veolia's actual work product, and Veolia's failure to meet the standard of care with regards to corrosion control and lead. As will be demonstrated in this appendix, Professor Bellamy's opinions are easily rebutted, and he fails to effectively rebut or oppose the opinions presented in my 2020 expert report. In addition to addressing the three opinion sub categories presented above, I include a fourth subsection addressing Professor Bellamy's failures to address or to rebut my opinions regarding the classwide nature of the impacts and damage that occurred throughout the City of Flint during the Flint Water Crisis.

[1] I do not take any position on whether the scope of Veolia's contractual obligations is a subject for expert testimony. I understand that plaintiffs intend to show the scope of Veolia's obligations principally through documentary evidence and testimony. Based on my review of the evidence, I believe plaintiffs' position is reasonable and that a reasonably competent professional engineer would have understood the scope of Veolia's work to include identifying the lack of corrosion control and making recommendations for appropriate corrosion control.

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One of the primary roles of my 2020 expert report was to memorialize and evaluate the common issues which tie together the residents of the Flint Water Cases as members of a class. Professor Bellamy fails to contest either the class certification issues or my opinions presented in my 2020 expert report that tie together the residents of Flint, who were all impacted similarly by the Flint Water Crisis.

The liability question regarding Veolia's work in Flint is: Did Veolia meet the standard of care in the services they provided to the City of Flint? Further, this raises the issues of whether Veolia provided the City with recommendations that would have allowed the City to avert or substantially mitigate the damage that occurred during the Flint Water Crisis. The answer to both questions is no.

# 2 Organization

The analysis of this report is presented in three sections. The first provides background on the issues in Flint regarding the Flint Water Crisis and the city-wide corrosion issues. The second presents analysis and rebuttal to each of the three primary opinions presented in Professor Bellamy's report. This section provides an additional fourth subsection analyzing Professor Bellamy's failures to address or rebut my opinions related to the class certification issues that tie together the residents of Flint. The third presents additional analyses of Professor Bellamy's report including his focus on issues that are aimed at distracting the reader from the core issues in Flint, and his presentation of misleading or inaccurate information.

# 3 Background

Veolia was retained by the City of Flint in early 2015 to address water quality issues in the City of Flint. While their initial focus was on disinfection byproducts, their actual work—as explained further below—encompassed a much wider scope. Veolia subsequently failed to adequately identify or address both corrosion and other water quality issues in Flint, or to make appropriate recommendations to address those issues, as any reasonably competent professional engineer would have done.

While Veolia attempted to assuage the concerns of the public, they were in fact ignoring the very real consequences of the Flint Water Crisis, including increased exposure to lead and damage to the plumbing systems throughout Flint. Veolia was engaged at a critical time in the Flint Water Crisis, and they could have averted or substantially mitigated much of the damage that occurred, had they acted. Instead, Veolia provided recommendations to dose the water with polyphosphate in an attempt to hide the red water discoloration, rather than to address the root cause issues, the highly corrosive Flint River water. Veolia characterized the problem as "aesthetic," failed to address the root cause issues of corrosive water in Flint, and failed to make appropriate recommendations for addressing the corrosive nature of the water in a manner that could have avoided substantial harm to human health and damage to pipes and fixtures in properties served by the City.

Veolia instead chose to provide recommendations to hide the signs of corrosion and used their reputation to try and assure the public and the City officials that the water was safe. Clearly, the water was not safe, as was witnessed by the boil water notices issued by the City, the disinfection byproduct levels, and the elevated levels of metals in the drinking water. Veolia failed to provide the technical expertise and sound engineering recommendations that could have limited the damage from the Flint Water Crisis, and as a result Veolia failed to meet their standard of care obligations.

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As Veolia should have ascertained, the vast majority of homes in Flint were built prior to 1986 and accordingly the homes with copper pipes were constructed with leaded solder.[2]

It was critical during Veolia's time in Flint that they recognize and address the danger that existed to the water users in Flint resulting from the distribution of corrosive Flint River water throughout Flint. This corrosive water impacted lead service lines (LSLs) and destabilized the high-lead scales contained in those systems. As demonstrated by the *Resident X* investigation (Roy and Edwards 2020), homes without LSLs or galvanized pipe also demonstrated high levels of lead during the Flint Water Crisis. The *Resident X* home had the highest measured water lead levels (WLLs) during the August 2015 sampling event, despite having neither a LSL nor any galvanized pipe in the premises' piping (Pieper et al. 2018, Roy and Edwards 2020). Therefore, the only source of lead in this home was from the newly corroding leaded solder and the high-lead brass in the faucets. These high lead brass fixtures are common to all water users in Flint. The high WLL indicates that there was active and aggressive corrosion going on in this home during the Flint Water Crisis, as there are no residuals of high-lead phosphate scales present in this home due to the lack of a LSL or galvanized pipe. Accordingly, the lead in *Resident X* home must be coming from the corrosion of leaded solders and brass fixtures within the home. Additionally, it is the presence of these high-lead brasses and leaded solders that continue to threaten drinking water quality in Flint with lead contamination.

The residential plumbing components now require replacement to restore their longevity, to restore the consumers' confidence in their water supply, and to permanently remove this source of lead contamination (in the same manner as the removal of lead service lines).

Essentially all the faucets in Flint contain very similar materials and techniques of manufacturing and installation; they were also all manufactured to comply with similar ASTM standards and installed under similar uniform plumbing codes. Most importantly all of the homes in Flint were supplied with the same corrosive Flint River water.

[2] In 1986, U.S.EPA published a seminal study explaining that the lead in tap water was caused by Brass Fixtures themselves rather than the water supply. According to U.S.EPA, "several studies document lead leaching from brass or bronze fixtures." In response, in 1986, U.S.EPA promulgated the "Federal Lead Ban," a set of amendments to the Safe Drinking Water Act which limited the maximum concentration of lead in brass to less than 8%.

# 4 Analysis and Rebuttal of Bellamy Opinions

## 4.1 Overview

Professor Bellamy presents a summary of his opinions on pages two through five of his report. Describing those opinions Professor Bellamy states (Bellamy 2021, p. 2):

*I offer the following opinions to a reasonable degree of engineering and scientific certainty. The following summarizes my conclusions and opinions concerning Veolia North America's (VNA's) professional services while contracted by the City of Flint (CoF) in February and March, 2015.*

Professor Bellamy organizes these opinions into three subsections (Nos. 1-3 below). I have added an additional subsection related to Professor Bellamy's failure to rebut my opinions regarding the common classwide issues in Flint (No. 4 below). These categories are presented as follows:

1) Veolia's scope-of-services and work product;
2) Veolia's activities related to potential corrosion control and lead;
3) Veolia's professionalism; and
4) Failure to rebut the common nature of the homes in Flint and the city-wide damage to the plumbing systems

## 4.2 VNA's scope-of-services and work product

Professor Bellamy summarizes his opinion regarding Veolia's scope and work product as follows (Bellamy 2021, p. 3):

*VNA's study and recommendations were professionally executed, meeting the requisite aims of its client and the standard-of-care for professional engineers.*

Professor Bellamy's opinion that Veolia's scope of work was narrowly limited, and that Veolia executed the work for which it was retained in a professional manner, is inconsistent with the evidence. That evidence demonstrates Veolia's broad scope of work and Professor Bellamy's opinions ignore the overarching responsibility of a professional engineer to identify and address issues that should be apparent to any reasonably competent professional engineer. The City of Flint's Request for Proposal (RFP), to which Veolia responded, set out a broad scope of work. Some of the details from that [redacted] [emphasis added]:

[redacted]

[redacted]

[redacted]

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[redacted]

In Veolia's response to the RFP, they claim that they would comply with the above requirements and provide the following through their [redacted]

[redacted]

The contract issued to Veolia utilized their proposal and the City's original RFP to define their contract scope. The contract between Veolia and Flint states ([redacted]):

[redacted]

As presented above, and in both my 2020 expert report and my main rebuttal report, the RFP from the City of Flint sought a consultant who could provide a wide range of technical expertise in water treatment and water quality management.

Professor Bellamy attempts to spin the City of Flint's needs as follows (Bellamy 2021, p. 24):

*The [City of Flint's] requirements for water quality expertise and operational assistance resulted from its recognized need to improve operations to address [disinfection byproducts], [Total Coliform Rule], and aesthetics.*

As demonstrated in the excerpts above, both the RFP and Veolia's response outlined a much broader set of subjects than disinfection byproducts, Total Coliform Rule, and aesthetic concerns. Regarding Veolia's response to the RFP, they presented a wide-ranging approach, and this document was ultimately integrated into their contract, thereby integrating it into the wording of their contract scope of work.

Professor Bellamy makes reference to these critical documents with footnotes, but fails to present the actual language from the Veolia's proposal, or their contract scope of work, to support his position. In fact, these documents directly contradict his opinion. Additionally, it is

disconcerting that Professor Bellamy characterizes the issues of system wide red water and high lead concentrations that fail the EPA lead Action Level in 85 percent of the homes in Flint (during the Flint Water Crisis), as aesthetic concerns.

It is clear based on the RFP and Veolia's proposal that corrosion was, in fact, included in Veolia's scope of work. Veolia's failure to adequately address corrosion and their failure to provide the required corrosion control technical expertise to assist the City of Flint, demonstrate that Veolia failed to meet the *aims of the client*. These aims included solving the water crisis in Flint and ensuring that Flint residents received quality water that would not damage their health or property. As will be discussed in the following sections, these failures regarding excessive lead contamination and excessive corrosion are some of the critical failures of Veolia with regard to the standard of care.

Professor Bellamy presents an inaccurate and misleading position regarding what the Veolia contact scope of work said and whether Veolia met those requirements. Professor Bellamy speculates that (Bellamy 2021, p. 26):

*The best method of establishing [Veolia's] understanding of the scope-of-services and the scope augmentations is to review the services [Veolia] provided.*

This position is nonsensical and wrong, and in any event fails on its own terms because Veolia in fact purported to address corrosion and corrosion control issues (but failed to do so in a competent manner). It is impossible to evaluate the require scope-of-services based solely on the work actually performed by a contractor. An evaluation of the scope-of-services requires:

1) A review of the agreed upon contract scope; and
2) A review of the actual work completed.

Bellamy's argument that Veolia met the required scope of services is based solely on the work they performed, absent of the agreed upon scope, and Professor Bellamy is wrong. If Professor Bellamy were correct in this position, there would never be a need for a contract or a fee dispute. His position, in essence, states that whatever work that the contractor performs meets the required scope of work, regardless of the actual agreements or scope of work definition in the contract.

The necessity to meet the contract scope of work requirements is commonly understood in the industry. Professor Bellamy further demonstrates how his positions do not follow industry standards by stating (Bellamy 2021, p. 27):

*…[Veolia] met the objectives of the written scope-of-services as well as its intent. This was confirmed by the delivery of services beyond those in the written contract document.*

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Professor Bellamy's statement is inaccurate. While I disagree that Veolia met their scope of work, let alone provided extensive services beyond those specified in the written contract and Veolia's proposal, it must be noted that providing services outside of their scope of work in no way establishes that Veolia did in-fact meet their scope requirements.

The scope analysis presented by Professor Bellamy is inherently contradictory. Professor Bellamy fails to present a convincing and supported argument that Veolia actually met their contractual obligations. He similarly fails to demonstrate that Veolia met the aims of their client, the City of Flint and ultimately the residents of Flint.

**Standard of Care**

Standard of care evaluations determine if the work performed by an engineer was consistent with the practice of engineering by an engineer with ordinary and reasonable care as exercised by an engineer in that profession, on the same type of project, at the same time and in the same place, and under similar circumstances and conditions. Professor Bellamy claims that Veolia met the required standard of care, but provides an unconvincing argument that lacks supporting evidence.

A thorough analysis of Veolia's failure to meet the standard of care with their work in Flint is presented in my 2020 expert report in Section 8. I identified a number of areas where Veolia failed to meet the standard of care. The following list presents a selection of those issues:

- Failure to identify the enormous risk to human health and property;
- Failure to evaluate corrosion potential utilizing CSMR;
- Failure to recommend changing water sources or blending water sources;
- Downplaying corrosion issues and failing to provide adequate warning regarding the substantial dangers it presented; and
- Failure to safeguard the public

Professor Bellamy fails to present a comprehensive and evidence-based analysis of these standard of care issues. Professor Bellamy's general response can be summarized as:

1) Veolia did in fact identify corrosion problems in Flint;
2) Veolia's recommendation regarding corrosion control met the standard of care;
3) Veolia's recommendations on disinfection byproducts did protect the public health; and
4) Source water evaluations were outside of Veolia's scope

I disagree with Professor Bellamy's evaluations of Veolia having met their standard of care. As many of these issues were addressed in my 2020 expert report, and not adequately rebutted by Professor Bellamy, I will not re-present those analyses. Regarding lead contamination and corrosion control issues, Professor Bellamy admits that Veolia accepted these corrosion issues in their scope of work and that Veolia was aware of corrosion problems in Flint. Yet, Veolia's

recommendations were entirely inadequate to guide Flint through their corrosion issues in the middle of the Flint Water Crisis. A thorough evaluation of Veolia's failures to meet the required standard of care with regards to lead contamination and corrosion control is presented in the following subsection and not addressed further here.

Regarding (3), Professor Bellamy's position presents a fundamentally misleading analysis that is not relevant to the core issues that caused in the Flint Water Crisis. Professor Bellamy focuses his analysis solely on Veolia's recommendations to reduce disinfection byproducts. In his opinion's summary, he states the following in support of his position without any evidence of same (Bellamy 2021, p. 3):

*VNA prioritized and focused evaluation efforts and recommendations on the important public health issues of disinfection byproducts (specifically THMs, which are cancer-causing compounds) and possible pathogen contamination (disease microorganisms) that threatened the health of Flint's citizens.*

*If implemented, VNA's recommendations would have resulted in actions necessary to assist in protecting public health and providing compliance with state and federal drinking water quality regulations, including the Lead and Copper Rule (LCR).*

While I disagree about the effectiveness of Veolia's treatment system recommendations (see my 2020 expert report), neither of these statements establish that Veolia met the standard of care with all their work in Flint. Professor Bellamy's focus on disinfection byproducts ignores central topics to Veolia's failures to meet the standard of care regarding corrosion control and lead. It is critical to recognize that the disinfection byproduct MCL addresses a chronic human health concerns that expresses itself over 70 years of exposure. On the other hand, lead contamination is an acute health concern that immediately impacts human health. His discussions regarding disinfection byproducts are not responsive to my opinions, and they do not establish that Veolia comprehensively met the standard of care.

## 4.3 VNA's activities related to potential corrosion control and lead

Professor Bellamy summarizes his opinion regarding Veolia's "activities" related to corrosion control and lead as follows (Bellamy 2021, p. 4):

*VNA's actions related to possible lead corrosion were appropriate and professional.*

Professor Bellamy presents the position that Veolia's actions regarding lead and corrosion control for the Flint water system were appropriate. As discussed in my 2020 expert report and my rebuttal report, Veolia's actions were not appropriate and failed to meet the standard of care that would have been applied by any reasonably competent professional engineer in these circumstances.

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**Veolia's Work on Corrosion**

A central piece of evidence to Professor Bellamy's arguments on lead and corrosion control is that Veolia did in fact recommend corrosion control. As was discussed in my 2020 expert report, and expanded on below, Veolia's work product simply does not support Professor Bellamy's opinion that Veolia met the standard of care with regards to lead and corrosion control in Flint, but instead shows that Veolia's performance fell fall short of what would have been expected from a reasonably competent professional engineer.

Veolia's final written work product was the March 2015 *Water Quality Report*. In that document, Veolia presented their recommendations for the Flint water system. Veolia's short and totally inadequate analysis of corrosion control in their report [redacted]

[redacted]

[redacted]

[redacted]

[redacted] Trueman, Krkosek, and Gagnon 2018 [redacted] Edwards and McNeill 2002 [redacted]

Basically, the Veolia recommendation that Professor Bellamy is describing as an *adequate and professional* handling of lead and corrosion control by Veolia is that they were fully aware of

excessive corrosion and potential lead contamination issues in the City of Flint, but that Veolia provided only a superficial evaluation of those issues and recommendations for treatment. Those treatment recommendations were provided without support and made no effort to convey the urgency of the threat to human health and property posed by the absence of corrosion control. Professor Bellamy argues at length about the appropriateness of Veolia's treatment recommendations, as they relate to disinfection byproducts, various aspects of the water system, and the return to DWSD water (which he opined was out of their contract scope). With regards to corrosion control issues, Bellamy argues that Veolia both did and didn't know of the issues at the time of their engagement, and that the treatment system modifications recommended by Veolia would have *"…lowered corrosion rates*." While I disagree with Professor Bellamy's positions, he does not contest my opinion that traditional water treatment methods and practices could have averted or substantially mitigated the Flint Water Crisis at the time that Veolia became involved in Flint.

Professor Bellamy argues that Veolia's *"…recommendations…were protective of public health and met the standard of care*." Professor Bellamy attempts to support his position by noting that *"…the potential for lead corrosion was identified and appropriate recommendations were made to the [City of Flint]."* This position is not supported by the evidence in this matter, and Professor Bellamy neither demonstrates that Veolia held paramount the safety, health, and welfare of the public, nor does he present documentation to attempt to support his opinion and position regarding Veolia's actions. Veolia's failure to provide effective recommendations to improve the Flint water quality, as they were obligated to do under their contract, were one of the root causes of their failure to meet the standard of care. As discussed at length in my 2020 report, Veolia did not protect the health and safety of the people of Flint. Veolia proposed methods to hide the corrosive water (polyphosphate), was aware of the potential for lead corrosion, and failed to address the critical issues of corrosion control and elevated lead levels resulting from the corrosive Flint River water.

While Veolia attempted to assuage the concerns of the public, they were in fact ignoring the very real consequences of the Flint Water Crisis, including increased exposure to lead contamination and damage to the users' plumbing systems throughout Flint. Veolia was engaged at a critical time during the Flint Water Crisis and could have averted much of the damage that occurred, had they acted. Instead, Veolia provided recommendations, such as dosing the drinking water with polyphosphate in an attempt to hide the red water discoloration caused by the corrosive treated Flint River water, rather than addressing the cause of red water and lead contamination.

Basically, Veolia failed to address the root cause issues of the Flint Water Crisis, which were the failure to provide corrosion control on the Flint River water. As was discussed in the previous subsection, the scope of their services was not limited to addressing solely disinfection byproducts. The scope called for a broad-brush approach that would draw on their expertise to evaluate the appropriateness of the Flint water treatment process for delivering quality drinking water, any issues in the distribution system that could compromise water quality, and to develop recommendations to assist the City with compliance of state and federal drinking water requirements.

Professor Bellamy attempts to argue that Veolia had no responsibility regarding the corrosive nature of the treated Flint River water. Even though Veolia failed to calculate basic corrosion indices in Flint, Professor Bellamy claims that they were aware of potential corrosion issues. Veolia's recommendations in Flint with regards to corrosion control were inadequate. Veolia recommended the use of a polyphosphate for corrosion control, to cover up red water generated by the widespread corrosion of iron plumbing components in Flint. Veolia misleadingly and inappropriately characterized these issues as "aesthetic" issues rather than as a symptom of a larger corrosion control problem that threatened health and property in Flint.

Veolia's presentations and final report provides an unclear and inadequate evaluation of corrosion. Veolia provides a recommendation to introduce a "phosphate," not specifying type or critical dosage information in their final report. Professor Bellamy argues that the Veolia actions on corrosion control and lead were *appropriate and professional*. I disagree with this opinion, and more critically, I do not agree that Veolia met the standard of care regarding *potential corrosion control and lead* in Flint.

## 4.4 Veolia's Professionalism

Professor Bellamy summarizes his opinion regarding Veolia's "professionalism" follows (Bellamy 2021, p. 5):

*VNA acted professionally during its engagement by meeting the standard-of-care for a consulting professional engineer. Its actions also corresponded with the Michigan Professional Engineers Code, National Society of Professional Engineer's (NSPE), and American Society of Civil Engineers (ASCE) codes of ethics and canons to protect public health, by informing the CoF of possible public health issues, and refraining from making comments outside its base of knowledge and without facts.*

Although Professor Bellamy describes this section as *Veolia's professionalism*, he actually attempts to establish that Veolia met the standard of care and that Veolia met their ethical obligations under the relevant engineering codes. Professor Bellamy presents the position that Veolia met the standard of care for a professional engineer. As discussed in this section, my 2020 expert report, and my rebuttal report, Veolia's actions were not appropriate and failed to meet the standard of care. Further, I disagree that Veolia's actions were protective of the public health, as discussed in my 2020 expert report.

### Engineering Codes

Regarding Professor Bellamy's claims of following the applicable engineering codes, the state of Michigan provides the following definition (NSPE, https://www.nspe.org/sites/default/files/resources/ pdfs/admin/publications/NSPE-PE-Definitions.pdf):

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*Michigan*

*Definitions: "<u>Practice of professional engineering</u>" means professional services, such as consultation, investigation, evaluation, planning, design, or review of material and completed phases of work in construction, alteration, or repair in connection with a public or private utility, structure, building, machine, equipment, process, work, or project, if the professional service requires the application of engineering principles or data.*

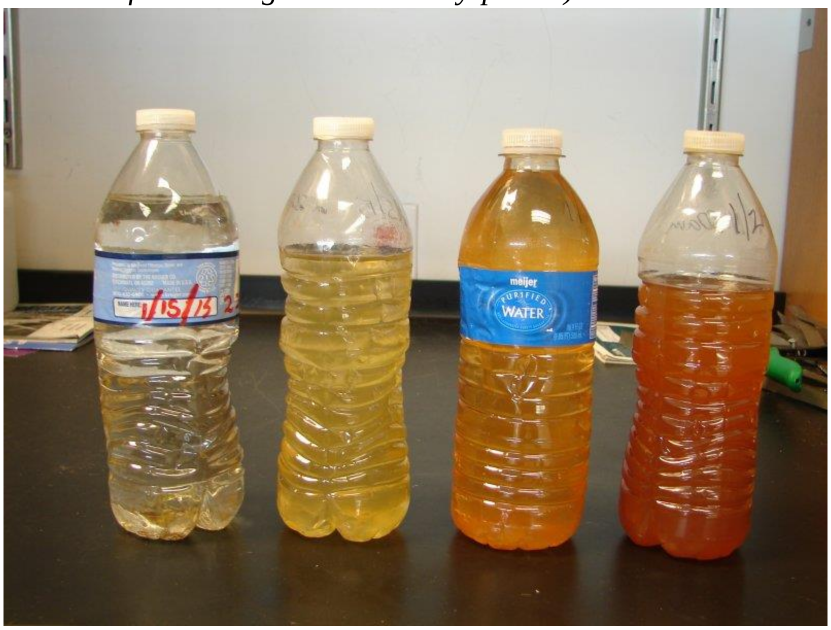
Adhering to the practice of professional engineering does not connote quality as a professional as defined by the State of Michigan, nor does it establish that Veolia met the standard of care. Professor Bellamy discusses the NSPE and ASCE codes. He claims that these codes establish the ethical requirements of engineers and those requirements are different than the standard of care requirements (Bellamy 2021, p. 20). Although I disagree with Professor Bellamy's position that Veolia's actions met the ethical requirements of professional engineers, the central issue addressed in my 2020 expert report is that Veolia failed to meet their standard of care. Veolia's professionalism is not relevant to that evaluation, and if anything, likely would have provided the City with a false sense of security regarding the reliability of Veolia's work.

Professor Bellamy continues to opine as follows:

*Protection of public health was at the heart of VNA's evaluations and work products, to include addressing SDWA regulations dealing with carcinogens (e.g., THMs and bromate), water borne disease microorganisms (e.g., Giardia), and lead and copper (e.g., neurological and other impacts) (Bellamy 2021, p. 5).*

While Professor Bellamy opines that *"…protection of public health…"* was "*at the heart*" of Veolia's work, this concept was not shown in their actions with respect to the absence of corrosion control and the need to immediately implement corrosion control to protect human health and property. Figure A4 -4.4.1 below shows an example of the water quality in Flint during the Flint Water crisis. These images were collected in January of 2015, shortly before Veolia's work in Flint. This picture is representative of the water quality being served in Flint during Veolia's work and are representative of what water users in Flint were expected to drink on a daily basis. As shown in this photo, even a lay person can identify that there were water quality issues in Flint. The well documented investigations and testing of lead throughout Flint demonstrate that Veolia's actions were not protecting public health.

*Figure A5-4.4.1: Images of discolored water samples collected in a home in Flint Michigan in January 2015 during the Flint Water Crisis. These photos were taken immediately before Veolia was the sole responder to the City's RFP titled "Water Quality Consultant RFP." (Time.com See What Flint's Poisoned Water Looks Like January 21, 2016;FlintWaterStudy.org; https://time.com/4189116/flint-michigan-water-study-photo/).*




These bottles were filled over the period of January 15, 2015 to January 21, 2015, and as can be clearly seen the quality of the water simply got worse and worse with time. It should be noted that as the red water intensity increased, so did the lead concentrations (Pieper et al. 2018). This is the situation that Veolia walked into in Flint, and it is the situation that they committed to solve in their proposal. Veolia committed to make better water for the City of Flint by using their water quality expertise. But they never identified the root cause of the red water in Flint, which was highly corrosive water that in addition to discoloring the water also was inevitably causing corrosion of lead-containing pipes, solders, and fixtures throughout the City.

**Standard of Care**

Some of the issues related to Veolia's failure to meet the standard of care are presented in the previous subsection on corrosion and lead. This section presents additional insights into how Veolia failed to meet the standard of care.

Professor Bellamy put forth the position that Veolia met their standard of care because they evaluated the water system and determined it could meet the regulated water quality standards (Bellamy 2021, p. 5):

*[Veolia] determined that the [Flint Water Treatment Plant] could meet state and federal drinking water regulations protecting public health if recommended treatment, operational, and management changes were implemented by the CoF. This met the standard-of-care for VNA's engagement.*

Professor Bellamy's claim is misleading and wrong. Determining that the water treatment plant could meet state and federal drinking water regulations does not establish that Veolia met the standard of care. Professor Bellamy is ignoring critical aspects of the Flint drinking water quality, which failed to meet regulations and also failed to protect human health. This system produced corrosive water, damaged plumbing systems, and generated increased level of lead contamination.

Veolia was involved at a critical time during the Flint Water Crisis. Had Veolia met their standard of care, they could have averted or substantially mitigated much of the damage that occurred in Flint. Instead, Veolia chose to provide recommendations to hide the signs of corrosion by adding polyphosphate, and used their reputation to try and assure the public and the City officials that the water was safe. Clearly, the water was not safe, as was witnessed by the boil water notices the City issued and the failure to meet the coliform disinfection requirements, the high disinfection byproduct levels, and elevated levels of metals in the drinking water. Veolia failed to provide the technical expertise and sound engineering recommendations that could have limited the damage from the Flint Water Crisis, and as a result Veolia failed to meet their standard of care obligations.

Examples of Veolia's failure to meet the standard of care are discussed at length in my 2020 expert report and include: Veolia failed to warn the City that the presence of highly corrosive water in the distribution system posed an immediate threat to human health and property; Veolia failed to conduct rudimentary corrosion evaluation calculations including CSMR; Veolia failed to recommend an immediate return to DWSD water ([redacted], as switching back to DWSD was ultimately the solution to the Flint Water Crisis in October 2015); and Veolia failed to recommend the use of an adequate corrosion inhibitor, or to optimize the corrosion control treatment at Flint. Professor Bellamy argues that Veolia did recommend corrosion control, and did determine that the water in Flint was likely corrosive and subject to issues with lead contamination. In fact, Veolia did not make adequate recommendations for corrosion control, and Veolia failed to address corrosion control as a part of their work. Professor Bellamy accordingly fails to effectively rebut my opinion that Veolia did not meet their standard of care.

## 4.5 Failure to rebut common nature of the homes in Flint and the city-wide damage to the plumbing systems

One of the primary roles of my 2020 expert report was to memorialize and evaluate the common issues which tie together the residents of the Flint Water Cases as members of a class. Professor Bellamy obscures the issues by ignoring what actually happened in Flint, especially with respect to Veolia's failures to meet their standard of care obligations both to the City of Flint and its residents. Professor Bellamy fails to contest the class certification issues and my opinions that tie together the residents of Flint, who were all impacted similarly by the Flint Water Crisis. Professor Bellamy does not contest that the plumbing systems were damaged during the Flint Water Crisis. Professor Bellamy does not contest that elevated levels of lead occurred throughout

the City of Flint. Professor Bellamy does not contest that the homes throughout the city utilize similar plumbing materials and were subjected to the same damage resulting from corrosive water.

# 5 Additional Analyses of the Bellamy Report

This section addresses additional topics discussed in Professor Bellamy's expert report that were not covered in the analysis of the opinions presented above. While these issues are not clearly addressed in Professor Bellamy's opinions, they require additional analyses because they present misleading information, much of which actually opposes Mr. Bellamy's main opinions.

## 5.1 Simultaneous Compliance

Professor Bellamy repeatedly references the complexities of (mandatory) simultaneous compliance with all of the Federal and State water quality standards. Regarding simultaneous compliance he quotes the following from the EPA LT2 guidance manual:

*In addition to the challenges of complying with the suite of microbial/disinfection byproducts (M/DBP) rules simultaneously, a water system must also ensure that changes in treatment to comply with those rules do not adversely affect compliance with other drinking water regulations [e.g. LCR] (Bellamy 2021, p. 16).*

The point that Professor Bellamy attempts to make here is that Veolia was properly managing the simultaneous drinking water standard compliance issues via their recommendations. Recall that the EPA Secondary drinking water Maximum Contaminant Level (MCL) calls for drinking water to be non-corrosive, and that Veolia failed to identify and make recommendations regarding the facts that (a) Flint water was highly corrosive, as Veolia's own analysis of the Flint water chemistry showed; and (b) Flint did not have *any* corrosion control method in place, even though it is well-known that corrosive water will damage pipes and fixtures and cause lead-containing pipes, fixtures, and solders to leach lead into the water. As shown in the photograph of the red tap water above, it was readily apparent to the naked eye that the Flint River water was very corrosive. Veolia's engineers had data that would have allowed them to easily identify the corrosive nature of the City's drinking water. Clearly what happened during the Flint Water Crisis demonstrates that the City was not providing drinking water that simultaneously complied with all drinking water regulations (as required by law), and that the Professor Bellamy's "*simultaneous compliance*" issue is just a red herring that seeks to distract from the gross deficiencies in Veolia's performance of its professional obligations. It is not acceptable for Veolia to solely make recommendations to address exceedance of the disinfection byproduct standards, at the expense of corrosion control or other regulated aspects of the water quality.

In support of Veolia's work in Flint, Professor Bellamy claimed the following:

*[Veolia] demonstrated its knowledge of water treatment plant complexity by assessing each of the treatment processes separately and in combination and linking recommendations together to address the overall need for compliance with regulatory requirements (Bellamy 2021, p. 16).*

Had Veolia addressed the "*…overall need for compliance with regulatory requirements…"*, Veolia should have automatically addressed (and corrected) the corrosion issues during the Flint Water Crisis. Veolia failed to do this. Professor Bellamy builds on this theme:

*VNA was tasked with providing recommendations to maintain compliance with state and federal drinking water regulations (Bellamy, 2021 p. 29).*

The drinking water regulations cover not only TTHM, but also lead, as set forth in U.S.EPA's Lead and Copper Rule set forth in 40 CFR Part 141 Subpart I. Veolia's recommendations did not lead to simultaneous compliance with all regulatory requirements. Professor Bellamy's assertion that Veolia's actions lead to simultaneous compliance are incorrect and misleading.

## 5.2 CSMR In Flint

As discussed in my 2020 expert report, the Chloride Sulfate Mass Ratio (CSMR) is a common tool in the industry to evaluate corrosion. Corrosion indices, such as CSMR are an essential tool for engineers in the water industry. Veolia failed to calculate the CSMR during their work in Flint. Veolia's failure to evaluate corrosion, and even to perform basic calculations including CSMR, represents one of the reasons that Veolia failed to satisfy the standard of care.

Contrary to this position, Professor Bellamy argues that, in fact, Veolia's calculations of CSMR would have been "*superfluous*" as they were already aware the water in Flint was corrosive and that CSMR would not have provided additional information. He further opines that CSMR calculations are not "*routinely practiced by utilities or consultants*." Professor Bellamy is incorrect in both of these positions. Regarding the knowledge and use of CSMR, Nguyen et al. 2011 reported the following:

*The detrimental effects of chloride and the benefit of sulfate on lead solubility provide a mechanistic explanation for the empirical value of the chloride-to-sulfate mass ratio in predicting trends in lead leaching from solder in at least some circumstances.*

The importance of the CSMR and the role of chloride in advancing lead corrosion and the role of sulfate in suppressing corrosion was apparent years before the Flint Water Crisis. Based on their published papers, competent corrosion experts like, Dr. Masten and Dr. Edwards would clearly disagree with Professor Bellamy's position that *utilities* and *consultants* don't perform CSMR calculations. In an attempt to obscure the issue of CSMR, Professor Bellamy presents the results from the Arnold 2020 study:

*Thus, it has been demonstrated by Arnold [2020], that the absolute CSMR value included in these categories is not necessarily a lead corrosion concern. Taken out of context and stating a priori that waters that fall into one of these numerical categories are a corrosion concern or not a concern is a misuse of the CSMR value (Bellamy 2021, p. 46).*

This statement by Bellamy is wrong on two fronts. First, Professor Bellamy is taking my statements and conclusions out of context. CSMR is a tool to determine if water has corrosive tendencies toward the galvanic corrosion of lead. It is not an *exclusive* method to identify corrosive water, but it is clear that a high CSMR level – such as Veolia's engineers could have easily calculated with the data set forth in their own notes – is a very strong indicator of the presence of both a serious corrosion control issue and the need to ensure that optimal corrosion control treatment methods are in place, as required by law (see my 2020 report Section 7 for a thorough discussion of these issues).

Second, Professor Bellamy is grossly mis-applying the findings of the Arnold 2020 study. Professor Bellamy argues that the broad system survey performed by Arnold marginalizes the useful role of CSMR. However, the CSMR has been diligently pursued by knowledgeable corrosion experts since Oliphant's observation in 1983. The Arnold 2020 study actually stated the following regarding CSMR:

*Approximately 75% of the systems surveyed had CSMR values greater than 0.5. No significant correlations between reported CSMR values and 90% percentile lead percentages were observed* (Arnold 2020, p. 36).

This statement has little bearing on the situation at Flint or the applicability of the CSMR. More than half of the utilities surveyed by Arnold utilized phosphate-based corrosion inhibitors, thereby suggesting that those systems were performing corrosion control, even though they had high values of CSMR. What the Arnold paper really demonstrates is that using proper corrosion control is a strategy that works to control corrosion in waters with corrosive tendencies, such as, those with high CSMR values. Flint did not have proper corrosion control method, and consequently it was documented that 85 percent of the homes sampled had drinking water that exceeded the EPA lead Action Level in August of 2015 (Pieper et al. 2018).

## 5.3 Corrosion in Flint

Professor Bellamy stated the following:

*Galvanic corrosion was not the primary contributor to Flint's drinking water lead contamination. The majority of lead identified in Flint drinking water was caused by release of lead scale particulates. LSLs were identified as the major source of the lead accumulated in the scale and so the major source of lead in Flint's drinking water.[87]" (Bellamy, p. 45)*

*[ [87] references Williams et al 2018.]*

Frankly, this statement is not supported by the Williams et al paper titled <u>Flint Pipe Rig for Corrosion Control Evaluation</u>. The Williams et al. work only evaluated corrosion in lead service laterals and was actually conducted after Flint had switched back to the DWSD water supply with OCCT following the Flint Water Crisis.

In fact, Williams et al. concluded their article stating:

*In addition, other potential lead sources present will remain, such as leaded brass fittings and fixtures, leaded solder, and lead accumulated in the scales of old galvanized, copper, or even plastic interior piping, even after all LSL segments are successfully removed in the future. Consequently, using a pipe rig for future treatment optimization to balance the control of lead from all sources is highly desirable (Williams et al. 2018, p. E43).*

A reading of the Williams work will quickly show that Williams did not determine that lead laterals were *"…the major source of lead in Flint's drinking water…"* as Williams did not address that question in a quantitative or comparative way. Further, Williams et al. points out a critical aspect for the City of Flint and the matters related to this Class certification: homes that had lead service lines, even those with plastic piping, had lead scales on the interior of the premise piping. Those lead scales provided sources of lead, when exposed to the Flint River water.

Professor Bellamy's conclusion that galvanic corrosion was a minor contributor to the Flint lead contamination crisis was both unsupported and is a misrepresentation of the Williams et al. findings. This statement is clearly proven wrong by the data collected by Pieper et al. 2018, where in majority of the home that failed the EPA Action Level had only high lead solder and high lead brass as a source of lead contamination. The *Resident X* home, as previously discussed, provides another concrete example from Flint of how non-lead lateral sources were a major source of lead in Flint.

## 5.4 Water Quality from Whitehouse Texas and White Plains New York

Professor Bellamy attempts to suggest that CSMR is not indicative of corrosive water by presenting two water quality data sets. One dataset is for the town of Whitehouse TX, a small town in Texas with a population of less than 10,000. The other dataset is for White Plains, NY which has a population of approximately 60,000. As will be explained below, the examples presented by Bellamy do not undermine the role of CSMR. In fact, as shown in White Plains, CSMR is an excellent predictor of a water's potential for causing corrosion concerns and lead contamination, such as, are occurring there.

Specifically, he stated the following:

*Further examples of CSMR values not necessarily indicating a "highly corrosive" water are Whitehouse, Texas with a CSMR of 7 and White Plains, New York with a CSMR of 3.95; both utilities complied with the LCR. By comparison, treated Flint River water had a CSMR ranging from 2.8-3.8 (Masten92)." (Bellamy, p. 46)*

While Professor Bellamy correctly identifies that these cities have high values of CSMR, the rest of his analysis and conclusions are off base and frankly wrong. Regarding White Plains, they purchase water from the New York City aqueduct and further treat that water with high doses of orthophosphate to reduce its corrosivity (White Plains Consumer Confidence Report 2016). If Flint had treated the Flint River water with the level of orthophosphates used in White Plains, it is likely the Flint Water Crisis would never have occurred. It should be noted that White Plains has been treating with orthophosphate since 1995. It should also be noted that White Plains very nearly failed the LCR requirements for lead in the CCR provided by Professor Bellamy even with this level of orthophosphate addition. Two of their thirty samples exceed the lead action level limit of 15µg/L (a third exceedance would have resulted in an action level exceedance).

Additionally, the EPA recently released revised LCR regulations. Under those revised regulations (which have not taken effect yet), the results in White Plains would have exceeded the Trigger level requiring them to do redo their corrosion control treatment, to expand their sampling base, and increase LCR sampling frequency.

Further complicating Professor Bellamy's attempted comparison, it is unclear what plumbing materials are in use across White Plains and how they compare to those in use in Flint. Based on the information provided by Professor Bellamy for White Plains, there is no indication whether the homes sampled in White Plains had lead laterals or have leaded solder or high-lead brass. As presented by Professor Bellamy, the data from White Plains does not support Professor Bellamy's position that CSMR "doesn't matter." Had he invested the time to read and study the data he provided, he would have determined that supports exactly the opposite of his position on CSMR.

Whitehouse, Texas is a small town of 8,000 people (2010 census). Professor Bellamy doesn't indicate how Whitehouse is related to Flint, and there is no data provided regarding when their houses were built, how many were sampled, what types of pipes they use, if they had lead service lines, etc. For example, if the houses sampled were newer construction, and there were no lead laterals, leaded solder, or high-lead brass, there would be no source of lead (maybe they have plastic piping). Professor Bellamy's comparisons between Whitehouse Texas and Flint are not helpful, and are not determinative of his positions on CSMR.

Professor Bellamy provided no guidance (other than their CSMR values) for why he chose these two water districts out of the 155,000 water districts in the United States. These two locations do not demonstrate that CSMR is irrelevant, and Professor Bellamy's references to these cities does not establish that CSMR had no role in Flint.

# 6 Conclusion

Professor Bellamy's central arguments are: Veolia acted professionally, Veolia provided appropriate recommendations regarding lead issues, Veolia met the standard of care, and that Veolia met the scope of work requirements. Professor Bellamy's report presents a misleading representation of the events in Flint and of Veolia's roles and responsibilities. As discussed in this analysis, it is my opinion that Veolia failed to meet the standard of care, they provided inadequate and incorrect recommendations regarding lead and corrosion control, and Veolia failed to provide recommendations that could have averted much of the harm caused by the Flint Water Crisis. Professor Bellamy's arguments do not effectively rebut or undermine my opinions related to Veolia and their work in Flint.

Professor Bellamy presents extended discussions on Veolia's scope, professionalism, and the soundness of their recommendations related to topics outside of corrosion (such as, disinfection byproducts). My analysis of Professor Bellamy's report focused on the actual scope of Veolia's obligations as a reasonable engineer would have understood the contracting documents and the work Veolia actually performed, Veolia's actual work product, and Veolia's failure to meet the standard of care with regards to corrosion and lead. Professor Bellamy's opinions are easily rebutted, and he fails to effectively rebut or oppose the opinions presented in my 2020 expert report.

One of the primary roles of my 2020 expert report was to memorialize and evaluate the common issues which tie together the residents of the Flint Water Cases as members of a class. Professor Bellamy fails to contest either the class certification issues or my opinions presented in my 2020 expert report that tie together the residents of Flint, who were all impacted similarly by the Flint Water Crisis.

The liability question regarding Veolia's work in Flint is: Did Veolia meet the standard of care in the services they provided to the City of Flint? Further, this raises the issues of whether Veolia provided the City with recommendations that would have allowed the City to avert or substantially mitigate the damage that occurred during the Flint Water Crisis. The answer to both questions is no.

**Appendix 5:**
**Analysis of Gagnon Declaration**

# 1 Introduction

This Appendix presents my analysis of the *Declaration of Graham Gagnon, Ph.D., P.Eng., January 6, 2021.*

Professor Gagnon was engaged on behalf of Veolia North America (VNA) to:

*…provide opinions about water chemistry and treatment issues relevant to the City of Flint, Michigan's use of the Flint River as a public drinking water source in 2014 and 2015. Specifically, I was asked to evaluate sources of lead in drinking water, NOM/TOC-related water quality and treatment issues, and corrosion control for treated Flint River water delivered to consumer taps after April 2014 (Gagnon 2021, p. 1).*

As will be discussed in this appendix, Professor Gagnon fails to address or effectively contest the issues related to class certification for the homes and residents that were subject to the Flint Water Crisis. In general, he presents unsupported positions, ignores critical data collected in Flint, and references irrelevant and outdated literature. Professor Gagnon fails to delineate between his opinions and the information that he believes supports his opinions..

This report is organized to provide a discussion of the sources of lead in Flint in Section 2 followed by a detailed analysis of the Professor Gagnon report in Section 3. Section 3 provides rebuttals to various topics and opinions presented by Professor Gagnon and a direct rebuttal to each of the conclusions presented in his 2021 report.

# 2 Lead Sources not from Laterals in Flint

This section provides the groundwork for a common flaw throughout the Gagnon report. Professor Gagnon argues that the predominant source of lead is the dissolution of "pipe scales that contained lead and other minerals on the inner surfaces of lead service lines" (Gagnon 2021, p. 7). As discussed in this section, the work performed by Dr. Marc Edwards's Team at Virginia Tech clearly demonstrates that lead from other sources, such as high-lead brass and leaded solder, was a critical source of lead during the Flint Water Crisis. Further, these sources impacted essentially every building in Flint due to the presence of leaded brass in most fixtures installed in these buildings.

The impacts of the non-lead service laterals sourced of lead (brass and solder) were well documented by Pieper et al. 2018. They stated the following regarding the sampling work performed in Flint (Pieper et al. 2018, p. 8127):

***Variation in WLLs Based on Service Line Material.***

*Based on the University of Michigan-Flint database, half (52%) of the homes sampled in August 2015 had copper service lines (n = 140), 16% had galvanized iron service lines (n = 44), 12% had partial or full LSLs (n = 32), and 19% had an unknown service line material (n = 51).*

During the August 2015 sampling round conducted by the Edwards Team, of the 269 homes, which included *Resident X* (the home with the highest drinking water lead measurements and without a LSL) only 12 percent (32) of the sampled homes had lead service lateral (LSLs).[1] Based on a personal conversation with Dr. Edwards, there is no reason to suspect that the 269 homes would have more or less LSLs than the 17 percent found during the FAST LSL removal.

As shown in Table A5-2.1 below, Pieper et al. 2018 reported that 85 percent (228 out of 269) of the homes sampled in Flint had measured lead levels above the required lead Action Level of 15 ppb during the August 2015 sampling round. This data demonstrates that if the lead and galvanized service lines were the primary source of lead in Flint, then the likely lead Action Level failures would be a total of 77 (or a maximum of 127 if all homes with unknown lateral material were in fact lead or galvanized).

However, the sampling event during the Flint Water Crisis indicated that the Action Level failures measured by Pieper 2018 were in 229 of the 269 homes sampled. Based on the physical evidence produced by Pieper et al. 2018, the most that the lead or galvanized service laterals could have produced is on the order of one half or less of the houses that failed the lead Action Level requirements of the EPA Lead and Copper Rule (LCR). Stated differently, the high-lead fixture components and the high-lead solder accounted for on the order of one half (and likely more) of the homes with elevated lead contamination documented in the City of Flint residences.

[1] Pieper et al. 2018 could confirm that only 12 percent of homes had LSLs. However, the FAST program in Flint removing lead laterals has established that the 17 percent of homes in Flint contained lead laterals is representative in the samples collected by Pieper et al. 2017/2018.

These results indicate that the majority of the lead in the Flint drinking water was not coming from the LSLs as the majority of homes do not have a LSL and yet the majority of the homes failed to meet the EPA lead Action Level (the FAST lateral replacement program has indicated that only 17 percent of homes in Flint had lead service lines), and this lead was instead coming from new corrosion of the high-lead fixtures and solder.

The Pieper et al. 2018 data directly contradicts Professor Gagnon's opinion that the high lead scales were the dominant form of lead contamination in the City of Flint.

*Table A5-2.1: Tabular summary of Pieper et al. 2018 data for the August 2015 sampling round of homes in Flint.*

| Homes by Lateral Type | Number | Percent | Percent failing Lead Action Level | Number failing Lead Action Level |
|---|---|---|---|---|
| **Total** | 269 | 100 | 85 | 229 |
| Known **lead** service lateral | 32 | 12 | | |
| Known **copper** service laterals | 140 | 52 | | |
| Known **galvanized** service laterals | 44 | 16 | | |
| Unknown material service laterals | 51 | 19 | | |
| Lead service laterals estimate based on FAST | 46 | 17 | | |
| Potential homes without copper service laterals | 129 | 48 | | |

Clearly, the majority of the lead contamination in the Flint homes came from the corrosion of the high-lead brasses and leaded solder, as the majority of these homes did not contain a LSL nor the associated high-lead scales.

# 3 Analysis of the Gagnon Declaration

The following sections present my analysis of the 2021 Professor Gagnon Declaration. The sections are divided thematically addressing various issue of the Professor Gagnon's position. Each section includes analysis of his position and an explanation of how his arguments and opinions are not supported by either the data or science. Section 3.4 presents a detailed rebuttal to each of the conclusions presented in the Gagnon Declaration.

## 3.1 Lead Sources in Flint

Professor Gagnon speculates that particulate lead is the main source of lead release without providing any convincing proof for this. As demonstrated by Pieper et al. 2018, particulate lead is only shown to be the main source of lead release in the homes with a lead service line (LSL). As was noted above, LSLs were only present in 17 percent of the homes. But as was clearly demonstrated in Pieper 2018, fully 85 percent of the 269 sampled homes failed to meet the lead Action Level requirement of 15 ppb, indicating both the lack of corrosion control and the presence of lead sources not related to LSLs. Pieper et al. 2018 demonstrates that the majority of lead in Flint came from the corrosion of internal premise piping, and not from particulate lead generated from a LSL. Therefore, the majority of the lead contamination came from the corrosion of high-lead brasses and leaded solder.

If a home doesn't have a LSL, there is no lead pipe for the lead particulates to slough off from. Yet, homes throughout Flint without LSLs are documented as having elevated lead during the Flint Crisis (discussed further below).

Professor Gagnon presents the following quote from Dr. Edwards's depositions to support his position on lead particulates (Gagnon 2021, p. 9):

*In his deposition, Edwards noted that "[t]here is so much particulate matter in sewage and lead likes to stick to the particles, generally speaking 85 percent or more of the lead, whether it is soluble or particulate, is captured in biosolids, and the lead in Flint, the vast, vast majority of it started as a particle. Virtually all of the lead from [a Flint residence studied by Dr. Edwards], virtually all of the lead we measured in Flint was -- was particulate." (Edwards Dep., p. 733). This confirms that the lead present in the Flint system was particulate and originated from sloughing off the lead pipe.*

Particulate lead clearly played a role in Flint, particularly in homes with lead service laterals. As described by Professor Edwards, the particulate lead originated from the sloughing off of the lead pipe. However, elevated lead was found in the majority of homes in the Pieper et al. 2018

research, indicating that other sources of lead (high-lead brass and leaded solder) were a substantial source of lead in Flint. This data directly contradicts Professor Gagnon's opinion regarding the source of lead in the Flint homes and businesses.

Further demonstrating the role of lead service lateral lead, the *Resident X* home had the highest lead level during Edwards's August 2015 sampling work in Flint. Yet, this home incorporated neither a lead service lateral nor any galvanized pipe (the components speculated by Gagnon to be the major source of lead in Flint). The fact that the data from the *Resident X* home reported the highest WLL of all 269 homes sampled in August 2015, indicates that there was active and ongoing corrosion of the lead-containing appurtenances in the Flint homes without the presence of a LSL, and that this form of corrosion played a critical role in the impacts on the Flint drinking water during the Flint Water Crisis. This fact directly contradicts the opinion of Professor Gagnon that the lead was entirely particulate (unless it originated from "sloughing off of the lead pipe").

Throughout his report Professor Gagnon picks and chooses from the available information on the Flint Water Crisis in an attempt to support his position regarding Veolia's work product. In doing so, Professor Gagnon ignores other critical factors, such as the role of lead from non-LSL sources. Contrary to his opinion that LSL particulate lead is the primary source of lead in Flint drinking water, other sources of lead are in fact the only source of lead in many homes, which was well documented in the Edwards research including the Pieper et al. 2017 and 2018 and Roy and Edwards 2020 papers.

## 3.2 The Ability to Predict Corrosive Tendencies

Professor Gagnon presents the position that it was impossible to prediction lead release in Flint. When Veolia became involved in Flint, the corrosive nature of the water in Flint was obvious based on the red water issues (of which Veolia was well aware). Utilizing available information, including visual observations and water quality data, Veolia should have been aware that corrosion and lead issues were a serious concern in Flint.

On this subject Professor Gagnon states the following:

*In other words, the complex properties of the scale in the Flint system, as characterized by the USEPA, make it nearly impossible to predict lead release using solubility models and indices. Thus, using such metrics would not have provided reliable information on controlling lead release. From the context of practice, along with basic water quality information such as pH, these indices would help to provide a very high level understanding of corrosion control requirements. It is expected that the amorphous scale impacts would have been heightened when elevated NOM and iron concentrations were present in the Flint system in 2014 (Gagnon 2021, p. 13).*

Surely Professor Gagnon recognizes that the Langelier Saturation Index (LSI) is usable as a model for lead phosphate scale stability (as the LSI is used with calcium carbonate scales)? This concept is illustrated graphically by Santucci and Scully 2020. Whether the scale consisted of hydrocerussite $Pb_3(CO_3)_2(OH)_{2(s)}$ or phosphohedyphane (Ca2Pb3(PO4)3(Cl,F,OH)(s)), or some other compound, all scales have a numerical factor ($K_{sp}$ scale solubility product) that would allow for the calculation of the stability of the scale in exactly the same manner as the LSI does for calcium carbonate. Just as Langelier did with the LSI, an equation could be developed which combines basic water chemistry with algebra (utilizing a $K_{SP}$ that determines when a scale will precipitate and when it will dissolve). More importantly, there were methods available to investigate the impacts of the water chemistry in Flint on the high-lead scales that were producing the particulate lead in the homes with LSL.

When the water is corrosive and/or capable of destabilizing the high lead scale, as it was in Flint, the issue is not that one needs to precisely predict what will occur; the issue is that one is blind without using some form of index to assist with the evaluation/recognition of the destabilization potential of the scale. The purpose of utilizing the corrosion indices is to provide an experienced corrosion control expert with a tool to help summarize or alert them to potential issues with the corrosivity before the switch over to the potentially corrosive water, and in the absence of specific testing for corrosion or lead contamination (which cannot be done before the water is distributed and it is too late).

After all, the water samples are expressly collected to determine whether the water is corrosive or not. The indices become irrelevant if properly collected samples are secured and proper testing is performed. The plumbing systems were already under corrosive attack and the water quality data speaks for itself. Simply stated, if the samples show that the lead concentration is above the lead Action Level, then the water is corrosive, indicating that the utility corrosion control program was not effective and did not provide sufficient reduction in lead levels to meet the LCR standard.

### 3.3 Total Organic Carbon (TOC) and Natural Organic Matter (NOM)

Professor Gagnon dedicated significant portions of his *opinions* section to the analysis of total organic carbon (TOC) and natural organic matter (NOM). These components are well established for having a role in the formation of disinfection byproducts. The NOM is more commonly referred to as color in the water (think of tea leaves infusing and coloring the water). Both Veolia and Professor Gagnon focused on reducing the NOM, as a method to reduce the formation potential of disinfection byproducts (i.e. TTHM) in the chlorinated Flint River water. There is clearly benefit in removing these compounds with respect to reducing disinfection byproduct production. However, the issue in Flint with regards to this treatment strategy was at what cost to the increased corrosivity of the water were improvements to disinfection byproducts made?

I disagree with much of Professor Gagnon's conclusions with regard to Veolia's recommendations on disinfection byproducts reductions. Moreover, it seems that he presents these issues to distract the reader from the class wide impacts that occurred to the residents and businesses in Flint as a result of supplying the corrosive treated Flint River water.

For example, Professor Gagnon presents information from a study performed by Arnold et. al 2012 that he claims supports the position that TOC removal can reduce copper corrosion. The Arnold et al. 2012 paper is titled *Controlling copper corrosion in new construction*, and presents an analysis that is applicable to new homes, and in fact has little application to the conditions in Flint as there was little new construction ongoing during the Flint Water Crisis. Further, Professor Gagnon presents a Figure 8, which is reproduced from the Arnold et al. 2012 paper, which presents copper concentrations in the new construction systems, comparing TOC removal with orthophosphate. Professor Gagnon claims this figure supports Veolia's actions, but it in fact does not. In fact, essentially all of the data points on the referenced figure exceeded the MCL for copper of 1,300 ug/l. Therefore, none of the proposed treatments would have been suitable for implementation in Flint due to their failure to meet the copper MCL.

The main conclusion of the Arnold et. al 2012 paper is that …*Temporary [Granular Activated Carbon] treatment may be a holistically attractive option to reduce copper corrosion problems in* ***new construction*** *in certain waters of high level NOM* [emphasis added] (Arnold et al. 2012, p. E310). Clearly, Professor Gagnon relies upon the Arnold et al. 2012 and then he speculates that Arnold's work could apply to existing older homes (over 99 percent of the homes in Flint were built before 1986) without supporting that inferential leap. His speculation is unsupported and disingenuous.

### 3.4 Veolia's Work on Corrosion Control

This section addresses two issues related to Veolia's work in Flint.

(1) Was corrosion control within Veolia's scope; and
(2) Did Veolia fail to meet the applicable standard of care with regards to corrosion?

Professor Gagnon's analysis of Veolia's work product in Flint indicates that Veolia was charged with addressing corrosion in Flint. While Professor Gagnon's attempts to exclude Veolia from this responsibility, he fails to do so. Veolia's work product, including their public presentations and contract, prove that Veolia was responsible for corrosion control.

Regarding the status of corrosion control under the watch of Veolia, he states the following:

*Polyphosphates have been used historically to reduce colored water caused by iron corrosion (e.g. red water). For example, a journal article published in 1957 refers to "glassy phosphates" (sodium phosphate glass) as a water treatment method (dosed in the range of 0.5 to 2 mg/L) to prevent deposition of calcium carbonate scale, and to control iron corrosion, stabilize dissolved iron, or a combination of the two (Illig, 1957). Other studies have reported the use of polyphosphates to prevent iron corrosion (McCauley, 1960; Williams, 1990; Facey and Smith, 1995; Cordonnier, 1997; Maddison and Gagnon, 1999). Polyphosphates sequester iron causing a decrease in red water (Lytle and Snoeyink, 2002). The use of polyphosphates has also been reported to be successful in reducing lead levels (Lee et al., 1989; Hulsmann, 1990; Boffardi and Sherbondy, 1991), however others have reported them <u>as being ineffective at reducing lead</u> (Edwards and McNeill, 2002) <u>[emphasis added]</u>* (Gagnon 2021, p. 33-34).

Professor Gagnon, in attempting to justify Veolia recommendations, is relying on dated non-pertinent literature from the 1950s, 1960s and 1990s. The Veolia recommendations relied on the antiquated literature which includes addition of polyphosphate to mask the effects of red water. If anything, the addition of polyphosphate (which is a complexing agent) would actually increase the corrosion rate of lead by dissolving lead from exposed lead surfaces. As reported by Trueman, Krkosek, and Gagnon 2018 (henceforth Gagnon 2018) Professor Gagnon's own research previously stated that:

*Polyphosphates are often added to drinking water to sequester iron and calcium, but they may form coordination complexes with lead, increasing its solubility*;

*Polyphosphates have been shown to enhance metal release from lead pipes in laboratory studies;*

*While polyphosphate … appeared to sequester/complex lead in solution, orthophosphate may have had the opposite effect … by reducing lead solubility*;

*Previous studies have highlighted the risks of polyphosphate in systems with legacy lead plumbing…*

Additional literature regarding polyphosphates has demonstrated increased levels of lead during their use. Ramaley 1993 reported elevated lead levels in systems using polyphosphates.

Professor Gagnon's approach is flawed and refuted in the literature by the work of Dr. Edwards, Pieper et al. 2017 and 2018, Triantafyllidou and Edwards 2007, and Triantafyllidou 2021. It is clearly refuted that polyphosphates are not corrosion inhibitors, and presenting dated literature does not change that fact.

Professor Gagnon relies repeatedly on antiquated corrosion research from over 50 years ago, instead of his own paper from 2018, which shows that polyphosphates increased the lead concentration in drinking water. This dated research and these dated technical papers are no longer accepted in the corrosion engineering profession as providing useful data on the subject of modern 21st-century corrosion control. It is of note that Professor Gagnon had to reach as far back as 1957 to find support for the use of polyphosphate to support Veolia's position, as follows:

*Polyphosphates have been used historically to reduce colored water caused by iron corrosion. In a paper by Illig (1957), sodium hexametaphosphate glass (a type of polyphosphate) was described as being used for control of calcium carbonate scale throughout Ohio and other areas of the Midwest, and that over 200 water companies were treating their water with glassy phosphates, including Flint, Michigan (Illig, 1957). It was also noted that although the original application of glassy phosphate was to prevent calcium carbonate scale formation, its most important role was as a corrosion inhibitor (for iron) – "Approximately 1,500 municipalities feed glassy phosphate to prevent "red water" caused by iron pickup in the distribution system" (Illig, 1957). The City of Flint was using polyphosphates over 70 years ago to control red water (Gagnon 2021, p. 35).*

Professor Gagnon is essentially referencing Calgon Bath Beads (note that this product has been discontinued and Calgon is no longer a company) as a form of treatment. This section requires a reference from 1957, because this topic isn't relevant based on the understanding of corrosion control today. It should be noted that there are over 155,000 water supply agencies in the United States, and therefore 1,500 is less than 1 percent of the total agencies, and should not be relied upon for Flint's issues in 2013. Polyphosphates are sequestering agents that are virtually ineffective against lead and copper corrosion, and in my opinion should not be used in drinking waters with exposed lead surfaces (includes piping systems using leaded solder).

Professor Gagnon further tries to support the use of polyphosphates, as recommended by Veolia, stating (Gagnon 2021, p. 36) [emphasis added]:

***Despite concerns in the literature surrounding polyphosphates and potential lead release**, they are still being used in the water treatment industry. For example, McNeill and Edwards (2002) evaluated phosphate inhibitor used at US utilities and reported that in a 2001 survey over 20% of participating utilities were still using polyphosphates (compared to ~20% using orthophosphate, ~30% using a zinc orthophosphate, and the remainder were using a blend of poly/ortho/zinc). Arnold et al. (2020) also reported that among 60 utilities in the United States surveyed: 54% used a corrosion inhibitor of which 28% used a blended-phosphate (e.g., mixture of polyphosphate and orthophosphate). Further, Arnold et al. (2020) noted that the 90th percentile lead concentrations for utilities using blended phosphates and orthophosphate was minimal.*

*Collectively these studies demonstrate that:*

*• Polyphosphates were previously applied in the Flint water system,*
*• Polyphosphates are largely used to address red water from iron suspensions in the distribution system, and*
*• Polyphosphate as a chemical additive is common in the water sector, particularly blended with orthophosphate.*

As admitted by Professor Gagnon (Gagnon 2018), there is concern over the use of polyphosphates with regards to potential lead release. The use of polyphosphates in water systems analyzed in the Arnold et al. 2020 paper does not mean they were an appropriate solution in Flint to address the corrosive water or mitigate lead release, as the Arnold article is a survey of current practices not a recommendation for the use of polyphosphates. Regarding the Edwards and McNeil 2002 reference (note Dr. Marc Edwards was in fact the lead author on that paper), the title of the paper describes the research well: *Effect of Phosphate Inhibitors on lead release from pipes.*

Their research concluded that (emphasis added) (Edwards and McNeill 2020, p. 79):

***[Polyphosphates] tend to increase the release of both particulate and soluble lead to drinking water**….Utilities need to consider these adverse effects whenever polyphosphates is used to prevent scaling or iron precipitation; **in fact, polyphosphates cannot be recommended for lead corrosion control.***

Professor Gagnon suggests that the Edwards and McNeill research provides support for his position that polyphosphates were an appropriate choice in Flint. In fact, even that paper demonstrates exactly the opposite (and confirms the position of my 2020 expert report): polyphosphate additions lead to increased corrosion and lead contamination problems in drinking water.

As I have cleared stated, the fact that one or many utilities are relying on dated and often negative value chemical addition is not a justification to consider its use in Flint. Supporting this position, the EPA 2016 Optimal Corrosion Control Treatment guidance manual states (USEPA OCCT 2016, p. 13) (emphasis added):

*Polyphosphates can also sequester lead and copper**, keeping them in the water and actually increasing the risk of exposure**…. Research has confirmed that **polyphosphates are generally not effective** on their own for controlling the release of lead and copper (Holm and Schock, 1991; Cook, 1992; Dodrill and Edwards, 1995; Cantor et al., 2000).*

Professor Gagnon continues as follows:

*Based on my experience, it is routine that a consulting firm may recommend that a corrosion control approach be implemented. However, it is ultimately the utility with the approval of the regulator that would be responsible for implementing the approved corrosion control approach. Despite VNA's recommendation that (a) the City of Flint initiate discussions with the State on the addition of corrosion chemical and (b) apply a recommended dose of 0.5 mg/L phosphate, these were not implemented by the City of Flint. The decision on what type of corrosion control chemical (e.g. orthophosphate vs. polyphosphate vs. blended phosphate) would have been discussed during consultation between the engineers and the State if it occurred (Gagnon 2021, pp. 34-35).*

Veolia (especially after acquiring Suez Environmental) is now the preeminent water quality firm in the world. Veolia does not need to recommend that the City acquire the skills of another consultant to conduct the Flint corrosion optimization evaluation, as they have sufficient in-house expertise to have provided this service to the City of Flint.

Veolia's recommendation to add polyphosphate appears to be their last-minute effort designed to mask the corrosion (red water) problem from the eyes of the citizens of Flint. Professor Gagnon states that *"[d]espite concerns in the literature surrounding polyphosphates and potential lead release they are still being used in the water treatment industry*" (Gagnon 2021, p. 36). As discussed in my 2020 expert report and the main body of this rebuttal report, the concerns over *potential lead release* from polyphosphate are significant (Gagnon 2018). Veolia's recommendation was to attempt to hide the corrosive nature of the water with a product which typically increases corrosion in the system. The fact polyphosphates are used at other locations does not justify that it was an appropriate recommendation in Flint. Based on these issues, it is my opinion that Veolia's recommendations were below the required standard of care.

### 3.5 Gagnon's Conclusions

The final section of the Gagnon Report is titled *Conclusions* and consists of a one-page-long list of bullet points. Gagnon declined to provide a basis for these conclusions. Selected points are addressed below, presenting the quoted bullet and a response.

*• Lead service lines were the predominant source of lead in Flint. Through the FAST program, it has become evident that the City of Flint was responsible for and owned the majority of lead pipe in the city.*

Response: Professor Gagnon ignores the fact that galvanized plumbing, solder, and brass components of fixtures are the only source of lead for 83 percent of Flint's homes. See the discussion in Section 2.

*• The removal of lead pipes in Flint has significantly lowered lead exposure through drinking water in the City of Flint. Research has also pointed to the limited impact that premise plumbing has had on lead concentrations in Flint since 2014.*

Response: The removal of the lead service laterals (LSL) in Flint could only improve drinking water quality in the 17 percent of homes that contained LSLs. While the improvement in drinking water quality and the reduction in risk by the removal of the LSL is significant for those homes with a LSL, it is irrelevant for those homes (83 percent) without LSLs. Roy and Edwards 2020 reported that in homes with a LSL, 16-28 percent of the lead exposure in those homes came from their premise plumbing. I do not concur that contributing 16-28 percent of the lead in drinking water in homes with a LSL and 100 percent of the exposure in homes without a LSL (83 percent of homes) demonstrates a "…*limited impact*…*since 2014*…"

*• Approximately 17% of the homes in Flint had a lead service line on the public or private portion of the address. Within these homes the concentration of lead would be highly dependent on a number of home-specific factors such as the volume of water collected, the temperature of the water, water age, and the length of the service line.*

Response: With the exception of the minority of homes that have lead service lines, I disagree completely with this statement. Roy and Edwards 2020 pointed out that during the Flint Water Crisis, *Resident X* had the highest measured concentration of lead despite having neither a LSL nor any galvanized pipe. As discussed previously, high levels of lead were documented in homes across Flint, the majority (83 percent) of which did not contain lead service laterals. Clearly, all of the houses were exposed to the same highly corrosive treated Flint River water, and they all shared lead containing materials in their faucets, valves, and solder in the homes with soldered copper plumbing. These high-lead content materials were subject to corrosion by the Flint River water and continue to be subject to corrosion and the introduction of lead into the drinking water

today. As stated previously, the only way to fully remove the continuing lead exposure from high-lead plumbing components is to replumb the homes with materials that meet the current EPA lead-free standards. This concept is identical to the handling of lead service laterals, which have been dug up and replaced with different materials throughout Flint following the Flint Water Crisis to forever protect the users of the Flint drinking water from lead contamination.

Professor Gagnon offers no evidence to support his speculation that there are home-specific factors that affected the impact of the Flint Water Crisis. He offers no evidence, such as water usage data for the homes, to support his supposition regarding how these factors would impact the water quality and lead concentrations in a Flint home. Additionally, the data collected by Pieper et al. 2018 showed that the majority of Flint homes (85 percent) had water quality substantially exceeding the lead Action Level of 15 ppb, indicating that these home share much more in common than the "*…home-specific factors…*" speculated on by Professor Gagnon's would lead one to believe. If the home-specific factors were determinant, then 85 percent of the homes would not have exceeded the lead Action Level during the August 2015 sampling performed by the Edwards Team.

Additionally, Professor Gagnon makes no effort to explain how the *Resident X* home, which had neither a LSL nor galvanized plumbing (Roy and Edwards 2020), had the highest lead values of any home sampled during the August 2015 sampling round in the Flint homes. *Resident X* contained solely high-lead content plumbing components that were corroded during the Flint Water Crisis, such as high-lead content brass and leaded solder. These components are (and were) contained in essentially all homes in Flint. The *Resident X* results demonstrate that Flint premises without LSLs suffered from high lead levels in their drinking water as much or more than homes with LSLs.

Clearly, the houses with a lead service lateral are not the only homes to suffer damage due to the corrosive nature of the water from the Flint River. Every premise in Flint had the same potential for producing high Water Lead Levels (WWLs), as was demonstrated by the testing on the *Resident X* home and the Pieper et al. 2018 data. To my knowledge, there is nothing unique that would differentiate what was observed in *Resident X* from either the 17 percent of the premises that had a LSL or the 83 percent that didn't have a LSL.

• *Lead release in Flint was predominantly from pipe scale that had accumulated on the lead service lines over the long history of the Flint distribution system. The scale contained significant quantities of lead. However, the nature of the scale was amorphous and non-uniform, which resulted in unpredictable release not predictable or describable by theoretical models.*

<u>Response:</u> – As discussed previously, Professor Gagnon's opinion regarding lead scales is irrelevant in the majority of homes without a LSL. The other sources of lead, including high-lead brass and leaded solder, are the elements that were corroded and which were primarily

responsible for the Flint Water Crisis. Clearly, homes with a LSL contained lead scales which played a significant role in the Water Lead Levels in those homes. However, homes without LSLs also experienced elevated levels of lead and corrosion, and Professor Gagnon offers no explanation of why those home were affected the same or worse than the homes with LSLs.

Therefore, there is no basis for his speculative (and incorrect) statement that "…*Lead release in Flint was predominantly from pipe scale that had accumulated on the lead service lines over the long history of the Flint distribution system*." Professor Gagnon produces no reference to support this speculative opinion, and even more significant is that he does not address the cause of high Water Lead Levels (WWL) in the 83 percent of premises in Flint without a LSL.

• *Indices such as LSI and CSMR are generally not exclusively relied upon for corrosion control in the water industry, and within the context of Flint – which was characterized by amorphous scale on lead pipe surfaces – these indices would in and of themselves have been inconclusive and unreliable for indication of any systemic lead release issues.*

Response: Professor Gagnon, in his defense of Veolia, is unwilling to concede that corrosion and water quality indices play an important role for corrosion engineers in evaluating corrosion issues. These indices are the industry standards upon which water quality/corrosion issues are characterized by corrosion engineers, as proven by their inclusion in the current primary references used by corrosion control professionals. Supporting this position, Masten et al. 2016 reviewed the events of the Flint Water Crisis and found that "…high values of CSMR and the Larson-Skold indexes of water entering the Flint distribution system should have raised serious concerns about the possibility of corrosion, especially given prior experience by water utilities" (Masten et al. 2016, p. 30).

These tools were available in the period 2013-2015, and as stated by Professor Masten, CSMR could have been used "…to predict the corrosivity of water toward lead piping…" (Masten et al. 2016 p. 31). It is clear that Veolia was aware of corrosion indices, and even calculated the values for one index: the LSI. Mr. Gnagy (a Veolia Engineer), testified that he calculated the LSI for the treated Flint water during his investigations in Flint. The claim that these indices are not relied upon in the industry is baseless. The indices play a critical role in identifying potentially corrosive conditions, and provide a critical indicator that additional investigation into corrosion concerns is required.

*• Natural organic matter (NOM) had a significant role in water quality in Flint. High concentrations of NOM resulted in violations of disinfection by-products in Flint. VNA correctly identified that removing NOM would be critical to improving drinking water quality overall and would decrease disinfection by-product concentrations in Flint.*

Response: The role of NOM and total organic carbon in the formation of disinfection byproducts is well established. However, reducing disinfection byproducts does not address the corrosion issues in Flint.

*• NOM likely also had a significant role in lead release from scales in Flint. Flint's high concentrations of NOM also would have minimized potential added benefits of corrosion control agents such as orthophosphate. VNA recommended several approaches to minimize NOM which would have improved distribution system water quality including lower lead concentrations. VNA's recommended treatment strategies for NOM removal were consistent with strategies recommend by the State of Michigan as well as those broadly accepted across the drinking water industry.*

Response: Professor Gagnon provides no basis for his speculative statements that NOM played a significant role in the scale release. As shown in Professor Gagnon's 2018 article (Trueman Krkosek and Gagnon 2018 – henceforth Gagnon 2018), interactions between NOM and corrosion rates are complex and not well established. Based on my experience, decreasing NOM is not appropriate as a primary corrosion control method. This position was similarly shown by Professor Gagnon in his 2018 article, which indicated that most of the potential impact of NOM on lead solubility was removed during typical coagulation and sedimentation water treatment processes, such as what was used in the Flint water treatment system. Removal of NOM is not an established corrosion control strategy, and Veolia shows no documentation that they aimed to reduce corrosion or lead scale release by reducing the NOM concentrations.

In fact, all that Gagnon says on the subject of lead release and NOM concentration is the following:

*Although high NOM levels are not predictive of lead release, their presence can have, under some circumstances, a direct effect on lead in drinking water. If water systems do not remove organic molecules effectively, observational, theoretical, and experimental evidence suggests that they can contribute significantly to lead release. In short, NOM can interact directly with lead by: 1) binding with lead, increasing its solubility, 2) dispersing lead colloids, leading to increased mobility, and 3) reducing lead to more soluble forms (Gagnon 2021, p. 20).*

As discussed above, there is no record that Veolia suggested that NOM control would provide a means to control corrosion in Flint; nor does Professor Gagnon provide any support for his conclusion that high NOM levels are linked to lead release.

Professor Gagnon correctly identified that NOM is present in the Flint water:

*In 2014, Flint's drinking water had exceedingly high levels of NOM, as indicated by THM levels measured in the distribution system (Gagnon 2021, p. 18).*

Response: I concur completely with this statement that there were excessive levels of NOM in the treated Flint River water. The high levels of NOM were known to Veolia and to LAN, but neither saw the role of NOM as a priority to recommend that Flint immediately switch back (or in the case of LAN, never switch away from) to the DWSD water source to eliminate the concerns of the high NOM levels.

Had LAN and Veolia insisted that the only way to avert the Flint Water Crisis was for the City to switch back, as soon as possible, to the DWSD as a source of supply (or never switch in the first place), then damage to premise piping caused by the Flint Water Crisis would have been substantially reduced or eliminated. The evidence of this statement is clearly demonstrated by the photo included in my rebuttal report (Figure 2.2), showing the McLaren hospital sink during the Flint Water Crisis and after the Flint water supply was returned to DWSD. The photos show the sink filled with red water during the Flint Water Crisis, and then filled with clear water after switching back to the DWSD water supply in the fall of 2015.

*• VNA's corrosion control recommendations, including consideration of phosphate and/or polyphosphate as a chemical inhibitor additive, were appropriate and supported by scientific knowledge and industry practice.*

Response: There is no role for polyphosphate as a corrosion control chemical in proper corrosion control in the 21st century, in my opinion, because of clear literature documenting that polyphosphate is not a good addition with respect to minimizing lead concentrations (Gagnon 2018) and Triantafyllidou 2021 Holm and Schock 1991). As noted by Edwards 2001 "[t]his highlights the danger of polyphosphate complexation of lead in the context of the U.S. Environmental Protection Agency action limit." Schock 1989 stated the following (emphasis added): "These studies showed that polyphosphates were often not only ineffective in reducing lead levels, but they could actually increase levels by complexation and solubilization of potentially protective films on the pipe. Some current research into the complexation capacities of several polyphosphates shows a potential for substantially *increasing* soluble lead levels in the absence of orthophosphate."

Veolia's statements about corrosion control in their report [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

## 3.6 Reliance on Edwards's Sewage Sludge Analyses

The inherent issues with Dr. Edwards's 2019 and 2020 sewage sludge are presented in detail in a separate appendix of this report. Professor Gagnon relied upon work that Dr. Edwards's group performed that ultimately utilized a flawed conceptual model to estimate water lead concentrations from the sewage sludge. The resulting findings and conclusions of that work were used as evidence to support Professor Gagnon's position, and they are inherently off base.

In brief, the Sewage Sludge Appendix demonstrates Edwards's model missed the fact that the sewage sludge lead concentrations are heavily influenced by the flow rate in the sewers and the amount of rainfall. The high flow events flush the dense lead particles that accumulate in the low points through the sewer collection down to sewage treatment system. Accordingly, the real-time release of lead from the plumbing systems is decoupled from with the lead measured in the sewage sludge at the WWTP. Therefore, the information presented in the 2019 and 2020 Edwards papers cannot be used to estimate water lead levels at the tap in the City of Flint.

Demonstrating how Professor Gagnon relies upon this data, he states:

*The biosolids work conducted by Dr. Edwards' team revealed that lead concentrations were comparable in 2011 and 2014. This finding speaks to the legacy challenge that lead service lines posed in Flint. Flint's drinking water in 2011 was provided by Detroit Water Sewerage District, sourced from Lake Huron, and had very different chemistry than water treated from the Flint River. Dr. Edwards' biosolids work delineates some factors that may have caused this increase in 2011. However, it is possible that chronic challenges such as water age in Flint's distribution system, iron corrosion from cast iron water mains, and low chlorine residuals, may have contributed (Gagnon 2021, p. 6).*

The lead levels in 2011 and 2014 cannot be evaluated in this manner due to the impact of high rainfall and the resulting storm water infiltration and inflow (I&I) and conclusions drawn from this type of analysis are wrong. As shown in the Sewage Sludge Appendix, the reason for the high lead sewage sludge data in 2011 was the high level of rainfall and this was misunderstood by the Edwards Team. The 2011 spring represented one of the heaviest rainfall periods historically documented in Flint, and accordingly there were very elevated sewage sludge lead measurements. These measurements do not indicate that the water lead levels were elevated at the taps during the 2011 events. This fundamental flaw in Edwards's work is detailed in its entirety in the Sewage Sludge Appendix of this report.

# 4 Conclusions

Professor Gagnon's report is not based on the real-world data and observations from Flint during the Flint Water Crisis. His report is full of dated examples from the literature (often dating back as far as the 1950s) that report data contrary to his own paper published in 2018. Professor Gagnon provides no convincing support for his speculations regarding both the events in Flint and Veolia's roles and responsibilities in Flint.

As a result, his opinions share the following common flaws:

- His opinions are simply unsupported speculation, and ignore critical data which oppose his conclusions;
- His opinions relied on the faulty Edwards WLL modeling data;
- His opinions repeat the obvious, and they should therefore be viewed with caution; and
- None of his opinion contest the system-wide impacts of the Flint Water Crisis.

**Appendix 6:**
**Analysis of Duquette Declaration**

# 1 Overview

This appendix addresses the *Declaration of David Duquette, Ph.D., January 6, 2021*.

Professor Duquette is an expert in corrosion processes involving jet engines and high thermal stress situations. A review of his professional papers indicates that he has only given a single presentation on water-based corrosion over his entire career, which was related to microbially induced corrosion (MIC). Professor Duquette has written no papers in over 250 publications on water or wastewater corrosion. He has mentored no doctoral or master's levels students on water or wastewater corrosion mitigation during his career.

Professor Duquette's report provides ten conclusions related to the Flint Water Crisis, and the resulting damage. Each of those ten conclusions is analyzed in this Appendix, demonstrating where Professor Duquette does not provide the required support for his conclusions and further fails to present any opposition to my opinions related to either the city-wide impacts of the Flint Water Crisis or the attributes qualifying the homes as a Class.

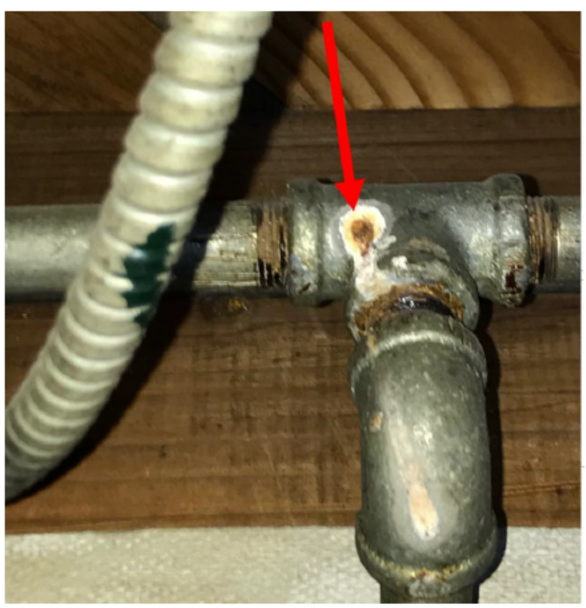
Professor Duquette concludes that there was no corrosion of exposed lead, including leaded solder and high-lead brass. This conclusion is unsupported, and has in fact been proven inaccurate by measurements of lead levels collected in homes throughout Flint. Professor Duquette's analysis is overly academic and frequently ignores the available data collected in Flint that opposes his conclusions (such as the *Resident X* home). Professor Duquette further based his conclusions on the sewage sludge work of Dr. Edwards. As presented in the separate Sewage Sludge Appendix, there were fundamental flaws in the conceptual model used in that work, and consequently the sewage sludge analyses from Dr. Edwards do not provide a reliable basis to support Professor Duquette's conclusions.

This report provides two sections of analysis. Section 2 analyzes and rebuts each of Professor Duquette's ten *Conclusions*. Section 3 analyses selected additional issues and provides criticism of Professor Duquette expert report. The photos that follow, Figures A6-1.1 and A6-1.2 will be discussed throughout this report. These photos show several things: First, they show the impact of new corrosion which is obvious due to the red water in Figure A6-1.1. Second, Figure A6-1.2 presents a piping photo taken by the Defense experts which shows the result of a through-the-wall pit, where there is zero pipe wall thickness remaining and the only thing keeping the holes from spraying is that the water salts (white deposit) have evaporated and temporarily plugged the hole. As will be discussed below, these photos demonstrate both ongoing corrosion during the Flint Water Crisis and damage to plumbing systems in Flint.

**Appendix 6:**
**Analysis of Duquette Declaration**

*Figure A6-1.1: Images of discolored water samples collected in a home in Flint Michigan in January 2015 during the Flint Water Crisis. (Time.com See What Flint's Poisoned Water Looks Like January 21, 2016;FlintWaterStudy.org; https://time.com/4189116/flint-michigan-water-study-photo/)*


*Figure A6-1.2: Example of leaking galvanized steel pipe from a home in Flint as documented by the defense (Duquette Underlying Data,* [redacted] *CPI Inspection Report). Note the original image file is presented with a red arrow added at the location of the through wall leak.*



# 2 Analysis of Duquette's Opinions

Professor Duquette's report ends in a section title *Conclusions*. As is presented in the analysis below, each of these conclusions is incorrect and baseless. These opinions further fail to contest the opinions presented in the Russell 2020 Expert Report addressing the class-wide common issues experienced in Flint.

Professor Duquette offers the following conclusions:

*1. There is no physical evidence that any of the lead in the water at the taps originated from corrosion of any component of the premise piping. Nor is there any scientific support for any corrosion of the water mains, service lines, or premise piping that resulted from the switch to the Flint River water (Duquette 2021, p. 26).*

This opinion is pure speculation and is wrong, as demonstrated below. Professor Duquette offers no evidence regarding the speciation or the origin of the lead that entered the drinking water of the people of Flint during the Flint Water Crisis. His position is entirely contradicted by the data from the Edwards Team widespread sampling in Flint; the fact that Pieper et al. 2018 reported that 85 percent of the homes that were sampled failed to meet the EPA lead Action Level of 15 ppb; the Flint *Resident X* data; and by his own site inspection photographs.

Professor Duquette concludes that there is no physical evidence of the corrosion of the high-lead brass and leaded solder. However, this position is undermined by the testing performed in Flint during the Flint Water Crisis, as documented in the Pieper et al. 2018 paper. That data shows that the overwhelming majority of homes that tested above the Action Level for lead in August 2015 in Flint had neither a LSL nor a galvanized service line, and thus demonstrates clear proof that the lead in those homes could have only come from one place: premise piping and fixtures. The following presents a detailed analysis of the homes sampled during the August 2015 sampling.

***Variation in WLLs Based on Service Line Material.***

*Based on the University of Michigan-Flint database, half (52%) of the homes sampled in August 2015 had copper service lines (n = 140), 16% had galvanized iron service lines (n = 44), 12% had partial or full LSLs (n = 32), and 19% had an unknown service line material (n = 51).*

Below is a table summarizing the Pieper et al. 2018 data quoted above:

**Appendix 6:**
**Analysis of Duquette Declaration**

*Table A6-2.1: Tabular summary of Pieper et al. 2018 data for the August 2015 sampling round of homes in Flint.*

| Homes by Lateral Type | Number | Percent | Percent failing Lead Action Level | Number failing Lead Action Level |
|---|---|---|---|---|
| **Total** | 269 | 100 | 85 | 229 |
| Known **lead** service lateral | 32 | 12 | | |
| Known **copper** service laterals | 140 | 52 | | |
| Known **galvanized** service laterals | 44 | 16 | | |
| Unknown material service laterals | 51 | 19 | | |
| Lead service laterals estimate based on FAST | 46 | 17 | | |
| Potential homes without copper service laterals | 129 | 48 | | |

As shown in Table A6-2.1 above, Pieper et al. 2018 reported that 85 percent (228 out of 269) of the homes sampled had measured lead levels above the required lead Action Level of 15 ppb during the August 2015 sampling. This data demonstrates that if the lead and galvanized service lines were the primary source of lead in Flint, then the likely lead Action Level failures would be a total of 77 (or a maximum of 127 if all homes with unknown lateral material were in fact lead or galvanized). However, the sampling event during the Flint Water Crisis indicated that the failures measured by Pieper 2018 were 229 of the 169 homes samples. The statement by Professor Duquette that there is no physical evidence of "…***any***…" of the lead coming from "…***any***…" component of the premise plumbing is patently wrong. Based on the physical evidence produced by Pieper et al. 2018, the most that the lead or galvanized service laterals could have produced is on the order of one half or less of the houses that failed the lead Action Level requirements of the EPA Lead and Copper Rule (LCR). Stated differently, the high-lead fixture components and the high-lead solder accounted for on the order of one half (and likely more) of the homes with elevated lead contamination documented in the City of Flint residences. These results indicate that the majority of the lead in the Flint drinking water was not coming from the LSLs (the FAST lateral replacement program has indicated that only 17 percent of homes in Flint had lead service lines), and this lead was instead coming from new corrosion of the high-lead brass and solder.

Further evidence of the premise plumbing corrosion and lead sources was presented by Dr. Marc Edwards (Roy and Edwards 2020). In their work in Flint, they identified that the highest lead concentrations during the August 2015 sampling round of their study originated from the premise plumbing of the *Resident X* house. This home had neither a lead service line nor galvanized pipe. Indeed, as Roy and Edwards 2020 stated about Resident X: *"To our surprise, this worst case home did not have any pure lead or galvanized iron pipe—it had only lead solder and leaded brass."*

Therefore, as explained above, the only lead source was the new corrosion of leaded solder and/or high-lead brass. This finding directly contradicts Duquette's conclusion. Moreover, the *Resident X* home proves that premise sources of lead contamination can lead to high water lead levels. *Resident X* is representative of the homes without a LSL that were sampled by the Edwards Team. It should be noted the data presented regarding *Resident X* in that paper does not rely on the sewage sludge data, and is therefore not subject to the criticisms described in the Sewage Sludge Appendix.

*2. The deposited scales of oxides, phosphates, carbonates, and hydroxides provided protection to the cast iron water mains, lead, galvanized steel and copper service lines before, during, and after the switch to Flint River water (Duquette 2021, p. 26).*

Professor Duquette is apparently dismissing the evidence, both physical and photographic, that the treated Flint River water exhibited high levels of corrosion. The water turned red from increased iron corrosion in the City's water mains and premise plumbing. That red color was readily visible to the residents of Flint, as shown in Figure A6-1.1 above. Red water complaints resulted immediately following the switch from DWSD water to Flint River water, indicating that the historical phosphate scales were being dissolved and destabilized by the corrosive water. Professor Duquette fails to support his claims that the scales provided substantive protection "…*during and after the switch to Flint River Water."* In reading Duquette's conclusions, one might believe that the scales are a permanent and impenetrable barrier against corrosion. However, the Flint Water Crisis observation and analytical data clearly support the opposite conclusion. As discussed in the response to (1) above, the work by the Edwards Team demonstrated active corrosion in the premise plumbing, in direct conflict with Professor Duquette's theories of impenetrable scale protection.

Similarly, there is an inherent conflict in Professor's Duquette's opinions on the role of the phosphate scales. He both argues that the scales protect the underlying base metals, and that the removal of the scales by the corrosive Flint River water is the primary source of lead contamination in the Flint drinking water. It has been well documented that the scales were dissolving and releasing lead which is demonstrated by the presence of detectable phosphate concentrations in the Flint drinking water (as there was no phosphate being added – any phosphate in the samples would have to come from the scale dissolution), after the switch to the Flint River water (Pieper et al. 2018). As stated by Pieper et al. 2018 on their work in Flint, "…the deterioration of leaded corrosion scale layers that accumulated over decades, at the home of Resident Zero, leached legacy phosphate to the water…" (Pieper et al. 2018, p. 8126).

**Appendix 6:**
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This scale destabilization process and the associated indicators of corrosion necessarily indicate that the scales were not protecting the pipes and fixtures, or these piping materials would not be corroding as they obviously were. It should also be recognized that years have passed since October 2015, and that the phosphate-based scales will have reformed during that time—especially with the current dosage of P-$PO_4$ of 3 ppm. That, however, does not indicate that the scales provided a foolproof impenetrable barrier during the Flint Water Crisis.

*3. The source of the lead that was released—before and after the switch to the Flint River system and back to the treated Lake Huron water—originated from the lead and lead reaction products that had deposited on the LSLs and associated piping in Flint's water distribution system during the decades that the system had been exposed to Lake Huron water (Duquette 2021, p. 26).*

I concur with Professor Duquette that a source of lead during the Flint Water Crisis was lead reaction product that built up inside Flint's piping from the homes with LSLs during the period when it was supplied with DWSD water treated with orthophosphate. However, Professor Duquette again ignores other sources of lead documented by Edwards and his team (See answer to 1 above). It is essential to recall that only 17 percent of the homes were served with lead service laterals. As Roy and Edwards 2020 demonstrated, these other sources of high-lead materials (the brasses and solder) contributed approximately 25 percent of the lead to the drinking water in the Flint homes with lead service laterals. Therefore, when there is no lead service lateral present, these features contribute 100 percent of the lead in those homes, such as, in the *Resident X* home.

The highest lead levels measured during the August 2015 round of sampling came from the home of *Resident X*, a residence without a lead service line or galvanized plumbing. Thus, the lead service laterals and their associate scales could not be the predominant source of drinking water lead in the Flint drinking water served in the houses without a LSL. Indeed, the premise piping and fixtures were clearly the predominant source of lead and the corrosion, impacting the majority of homes throughout Flint. As discussed in my 2020 expert report, these items are capable of releasing high amounts of lead into the Flint drinking water.

*4. The lead released to the premises during the period that the piping was exposed to Flint River water was a result of discontinuing the addition of orthophosphate at the time of the switchover in water supplies which resulted in instability and deterioration of the lead phosphate scales that had developed on LSLs. There is no physical evidence that any of the lead in the water at the taps originated from corrosion of any component of the premise piping. Nor is there any scientific support for any corrosion of the water mains, service lines, or premise piping that resulted from the switch to the Flint River water (Duquette 2021, p. 27).*

This issue is already addressed in the response to (1) above. However, Professor Duquette's opinion is a direct admission that it was below the requisite standard of care not to insist on the incorporation of modern corrosion control when the switch was engineered in 2014 (i.e. LAN's role). Supporting this position, he stated that the lead released during the Flint Water Crisis was a direct cause of the failure to add orthophosphate to the treated Flint River water.

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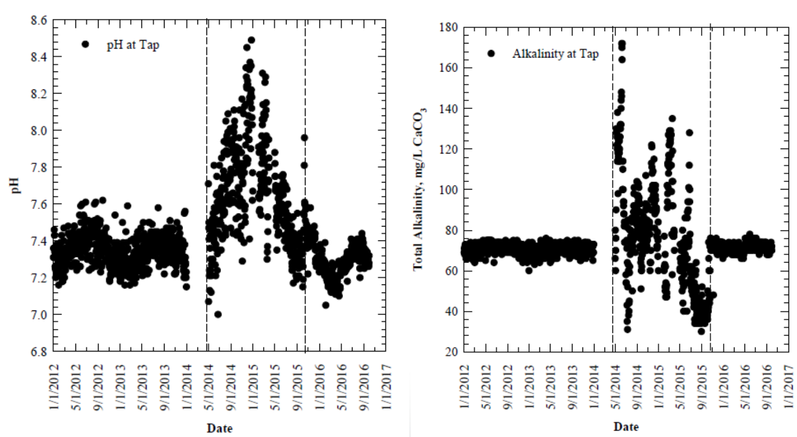
As discussed previously, work by Edwards's Team demonstrated that lead was present in the majority of homes without lead service laterals or galvanized lines, indicating that in 2015 (during the Flint Water Crisis) there was active and aggressive new corrosion of the exposed lead solder and high-lead brass surfaces occurring in at least the 83 percent of Flint homes without a LSL. Critically, Pieper et al. 2018 found that 85 percent of the homes sampled failed to meet the lead Action Level of 15 ppb during the August 2015 sampling, in the heart of the Flint Water Crisis. Additionally, there is ample photographic evidence of the accelerated corrosion of the piping within the City of Flint due solely to the treated Flint River water as discussed later in this report.

Professor Duquette is again ignoring the corrosion which was generating the red water complaints in the Flint distribution system. Clearly, there was corrosion occurring in other plumbing components in the Flint distribution system, including the cast iron water mains, the service lines, and the premise plumbing. Additionally, even if Professor Duquette's conclusion were correct—which, as just explained, it is plainly not—his opinion that lead was released into the drinking water due to the discontinuance of orthophosphate supports the existence of classwide issues. His position demonstrates that everyone in Flint received the same corrosive water and that any damage that occurred was directly attributable to choices made by those managing or consulting on the water supply.

Professor Duquette is also ignoring the fact that the water supplied during the Flint Water Crisis was extremely unstable and of highly variable water quality. This water immediately attacked the existing high lead phosphate scales in those houses with LSLs, as shown in the graphs of pH and alkalinity below.

*Figures A6-2.1.A and A6-2.1. B: pH (left) and alkalinity (right) of the treated water supplied in Flint from 2012-2017. The vertical dashed lines show the period the system was supplied with Flint River water from approximately May 2014-October 2015. Note the dramatic variability in both parameters during operation on the Flint River water as compared with the DWSD periods (January 2012-May 2014 and October 2015-October 2016). As can be seen in the plot on the right, alkalinity was extremely variable and was at low levels for multiple periods during the production of the Flint River water, whereas both were very stable when the DWSD water was being supplied.*



*5. There is no evidence that the shift from Lake Huron water to the Flint River water resulted in any accelerated corrosion of the City's galvanized steel pipes, whether service lines or within premises [sic] The City's galvanized pipes, per se, were not a source of lead before or after the shift to the Flint River water. Any lead that was released from the City's galvanized pipes was released from secondary deposits of lead reaction products that had been transported to the galvanized steel surfaces through sloughing of scales from LSLs during decades of exposure to the Lake Huron water supply (Duquette 2021, p. 27).*

Professor Duquette has no evidence to support this conclusion. I am aware of no data—and Professor Duquette cites none himself—that supports his assertion that there was no corrosion of the City's galvanized pipes. Moreover, Professor Duquette's assertion is directly contradicted by the photos from his own home inspections. Those photos, which are presented in the following section, clearly show through-wall pipe pitting indicative of corrosion of premise galvanized plumbing.

Through-wall pipe pits indicate that the pipes have failed due to leakage, and further indicate that the pipe wall thickness has been reduced to zero in the pitted area (i.e. the pipe is missing at the location of the pit). In steel pipe, the formation of the pit produces iron oxide (red water), which actively sloughs off into the home's drinking water. These leaks prove that the scale inside of the pipes was not, in fact, sufficiently protective to protect the pipes from the corrosive Flint River water, and therefore proves the falsity of Professor Duquette's speculative assertion.

*6. There is no evidence that galvanic couples resulted in any accelerated corrosion of any of the City's infrastructure due to the shift to Flint River water. Any galvanic couples that may have been present in the City's water supply infrastructure would have been isolated from the Flint River water, with layers of protective scales that were deposited during the pre-April 2014 period when the system was supplied by Lake Huron water (Duquette 2021, p. 27).*

This is another example of Professor Duquette offering a conclusion that is not only speculative, but is also directly contradicted by available evidence. As indicated in my expert report, lead goosenecks used to join/seal cast iron pipes are a major source of galvanic lead corrosion products in drinking water systems with cast iron water mains. The galvanic corrosion rates of lead couples have been shown to be aggravated by increases in the Chloride to Sulfate Mass Ratio (CSMR). The CSMR was necessarily increased as a result of the City accepting the recommendations of Veolia to increase the ferric chloride coagulant dosage. As discussed throughout this Appendix, the inspection reports performed by the defense and provided as part of Professor Duquette's declaration clearly show signs of damage resulting from galvanic corrosion between dissimilar metal couples in the premise plumbing. This corrosion directly resulted in the release of lead and other brass components into the residents drinking water.

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*7. Brass fittings in the City's premises[sic] could not have contributed any lead to the water during the period when the system was supplied with water from the Flint River. Any lead that may have been incorporated in the City's brass fixtures would have been incorporated into the corrosion product of the brass, as well as the scale that had been deposited on the brass during the pre-April 2014 period when the system was being supplied by Lake Huron water. There is also no evidence of any increased corrosion damage of the City's brass fixtures due to the switch to Flint River water (Duquette 2021, p. 27).*

Professor Duquette claims that the high lead brass **"…could not have contributed any lead…,"** but there is sound scientifically collected evidence to the contrary. This evidence of sources of lead was discussed in the response to Conclusion (1) above, and demonstrated by the Pieper et al. 2018 sampling analysis and the *Resident X* work presented by Roy and Edwards 2020. In those papers, houses without a lead service lateral clearly had elevated levels of lead, which necessarily originated in premise plumbing. This conclusion, like so many of Professor Duquette's conclusions, relies on his assumption that all of the piping in Flint was protected by a scale. As my prior responses have already shown, there is clear evidence that the scales present did not, in fact, prevent corrosion of the base metals in piping and fixtures, and Professor Duquette has offered no evidence to the contrary.

*8. Visual examination of the internal plumbing in representative homes in Flint indicated no observable corrosion damage to any of the plumbing supply lines or fixtures. The plumbing that was inspected included copper and galvanized pipes as well as brass fixtures. (Corrosion Probe inspections, 12/20) (Duquette 2021, p. 27).*

Professor Duquette's visual examination of internal plumbing in Flint proves the opposite of what he concludes. As pictures in this report show, the galvanized pipes in the two homes inspected had through-wall pits as a direct result of corrosion. These leaks (pits) indicate that the scale inside of the pipes did not have sufficiently protective scales to protect these pipes from the corrosive Flint River water. Moreover, no pipes were removed or opened to allow for inspection of the interior surfaces, where internal corrosion would be seen. Dr. Crowe, who did the inspections for Professor Duquette, never bisected any pipes to allow for the inspection of the internal plumbing corrosion, and there is therefore no basis for this opinion.

Dr. Crowe found and reported that the plumbing materials at both residences he inspected had high lead levels in the plumbing materials (tests were done by XRF on the **externa**l surfaces), as is typical for homes constructed prior to 1986. Dr. Crowe's testing revealed that the lead levels in 70 percent of the pipes and fittings tested exceeded the current allowable lead content for drinking water fittings by a factor of tenfold.

Professor Duquette failed to utilize the information available to him from the inspection reports he attached to his Declaration. These inspection reports clearly documented the precise corrosion damage that he denies occurred.

*9. Virtually every home in Flint, Michigan has different plumbing components and only a relatively small percentage of the homes were supplied with lead service lines. There is no physical evidence or scientific basis that any of the internal piping has suffered from other than conventional corrosion as a result of exposure to water of various chemistry over decades (Duquette 2021, p. 27).*

By the defense's own admission, only 17 percent of the Flint homes had lead service lines. The Edwards Team sampled 269 homes, 80+ percent without lead service laterals, yet 85 prevent of the homes had water lead levels (WLL) that exceeded the US EPA lead action level of 15 ppb. Moreover, while it is true that components in the various homes in Flint are different in aesthetic styles, they all contain very similar materials, techniques of manufacturing, and techniques of installation; they were all manufactured to comply with similar ASTM standards; and they were installed under similar plumbing codes and regulations at the time of installation. Additionally, all of the homes were supplied with the same corrosive treated Flint River water. As discussed in my 2020 expert report, the Flint Water Crisis impacted the homes of Flint including those with a variety of different plumbing configurations that form the Class. One only has to refer to Professor Duquette's photographs to see the corrosive effects of exposure to the corrosive Flint River water on the piping in the City of Flint.

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**Analysis of Duquette Declaration**

*10. Dr. Russell's contentions that exposure to the Flint River water for approximately 18 months resulted in either excessive corrosion of premise piping, or to the possibility of extraordinary releases of lead, are unsupported by any physical evidence or by any scientific engineering concept. As a result, there is no justification for [sic] replacement program of any premise plumbing components (Duquette 2021, p. 27-28).*

For brevity's sake, I'll refrain from reproducing the entirety of my 2020 expert report, which provides clear evidence of exactly the opposite of Professor Duquette's opinion. Needless to say, the only way Professor Duquette could arrive at this conclusion is by purposefully ignoring numerous indicators of corrosion and the resulting lead release. These indicators include: the corrosive water impacts at the Flint GM engine plant, Professor Duquette's own photographs showing through wall pitting, the Pieper et al. 2017/2018 study data, numerous other studies from the Edwards Team, and the obvious ubiquitous presence of red water after the switch to the Flint River water.

The measured water quality data speaks in a true evidentiary sense to the extraordinary releases of lead and iron. The evidence is clear for excessive lead release and corrosion of premise piping (*Resident X* and the Pieper et al. 2018 data), and that data is utilized as evidence of the same throughout my Rebuttal and Expert Reports. The same is true with respect to the studies mentioned in my expert report on the corrosive effects of the Flint River water, which accelerated corrosion by a factor of approximately 10-fold.

Perhaps Professor Duquette was not familiar with the General Motor (GM) engine plant that found the treated Flint River water too corrosive to be used for the manufacturing of car engine parts. GM required the cash-strapped City of Flint to spend over $400,000 to reconnect the GM plant back to the DWSD water via Flint Township. Yet, Professor Duquette's position remains that the water was still good enough to drink, and did not corrode the premise plumbing of the residents of Flint's homes and businesses in any way.

As discussed previously, Professor Duquette has ignored the evidence of corrosion in Flint, including the in-home photo documentation of corrosion performed by Dr. Crowe and presented with his Expert Report. Corrosion has occurred and the Flint River water was documented as being much more corrosive the previous and current water source (DWSD). Elevated levels of lead were measured and documented throughout homes in Flint.

# 3 Additional Analysis of Duquette Report

This section presents a rebuttal using selected text sections from various components of Professor Duquette's report. These text selections from his report represent examples of Professor Duquette's speculations regarding the events that he postulates never happened in Flint during the 2014-2015 period (i.e. the Flint Water Crisis). The following sections provide a quote from the Professor Duquette report followed by a response and/or rebuttal.

(1) Professor Duquette speculates as follows:

*To reiterate, virtually all of the piping system at Flint was, and is, covered with a thick scale. The scale that was, and is still in place was shown in the two samples of galvanized pipe that were collected from the system (Figure 1). The scale is an effective diffusion barrier limiting access of water to the metal surfaces. Since the inner scale remained intact during exposure to the Flint River water, it is evident that exposure to Flint River water had no significant effect on corrosion of the Flint distribution system, including premise plumbing components* (Duquette 2021, p.10).

Plumbing-system inspections were performed by Dr. Crowe on behalf of Professor Duquette and documented in Professor Duquette's report. While onsite, Dr. Crowe had the opportunity to document the existing wall thickness of the pipes via non-destructive means (such as ultrasonic measurements), but chose not to do so. These measurements could have provided a concrete basis regarding his speculation on pipe wall thickness and the role of protective scales. These non-destructive testing means would have (likely) shown extensive wall thinning of the pipes resulting from corrosion.

Professor Duquette's speculation on the nature and thickness of the pipe scales on residential piping systems is simply not backed with sufficient data. He is speculating, at best, that these scales were present based on antecedent conditions in Flint (presence of lead and the addition of orthophosphate since 1996). Professor Duquette provides no substantive references as evidence to support his statements.

Professor Duquette also ignores the statement of Michael Schock, one of the primary US EPA experts on the corrosion of lead and copper in drinking water. Mr. Schock testified that in his opinion the scale in Flint would have been destabilized immediately upon the introduction of Flint River water into the Flint's distribution system, thereby initiating the removal of the scale.

Further, Professor Duquette is ignoring clear evidence to the contrary, as can be seen in this photo (Figure A6-3.1) taken in Flint in 2015 at the *Resident Zero* home. As shown in the pictures, iron-based corrosion was occurring, and the pipe scales were not protecting the plumbing systems, as Professor Duquette speculates above.

*Figure A6-3.1: Images of discolored water samples collected in a Residence Zero home in Flint Michigan in January 2015 during the Flint Water Crisis. (Time.com See What Flint's Poisoned Water Looks Like January 21, 2016;FlintWaterStudy.org; https://time.com/4189116/flint-michigan-water-study-photo/)*


(2) Professor Duquette states:

*If it is assumed (conservatively) that half of the pipe wall for Flint's steel piping had corroded away during the period 1967 to 2014, by Dr. Russell's estimate the entire remaining pipe wall should have corroded away by late 2015. Obviously, that did not happen (Duquette 2021, p. 7).*

Professor Duquette is simply wrong here. As shown in his own photographs (reproduced below) in Dr. Crowe's inspection report on the Flint residences at [redacted] the wall thickness of these pipes is essentially zero, and what I predicted would happen did, in fact, happen, and the pipe wall was destroyed by corrosion. The white deposits shown on the outside of the pipe are evaporated salts deposited during the leak. These deposits act as a cork to stop the spraying of water from the through-wall pits were observed in at least two locations documented by Dr. Crowe.

As predicted in my Expert Report, and as confirmed by Dr. Crowe's photos, the Flint River water demonstrated a propensity for pitting. The low chlorine residual conditions in the Flint River water likely allowed for biological slime growth, which then combined with the high level

of water corrosivity to generate an intense corrosion attack on the premise's piping. Examples of these leaking plumbing components documented by Dr. Crowe follow.

*Figure A6-3.2: Example of leaking galvanized steel pipe from a home in Flint as documented by the defense (Duquette Underlying Data,* [redacted] *CPI Inspection Report). Note the original image file is presented with a red arrow added at the location of the through wall leak.*

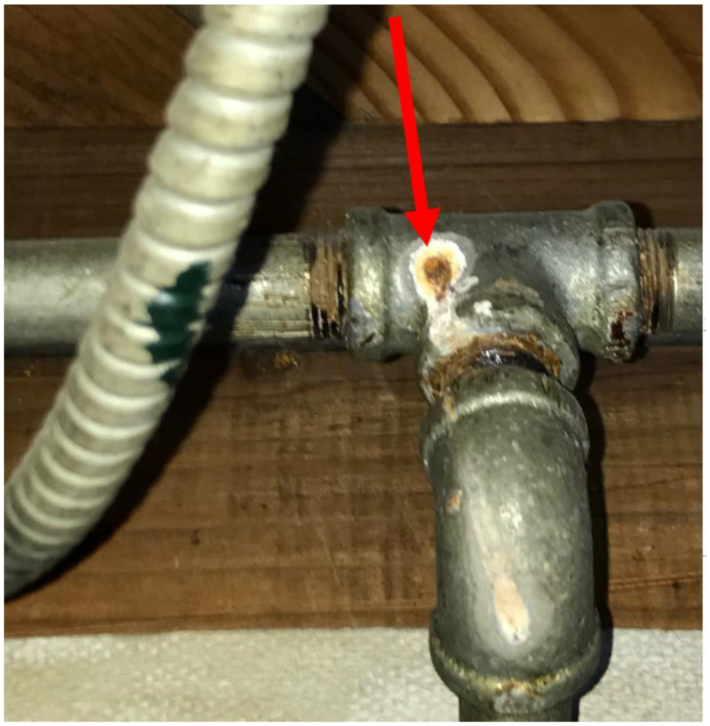


*Figure A6-3.3: Example of a leak formed at galvanic couple between galvanized steel and brass from a home in Flint as documented by the defense (Duquette Underlying Data, [redacted] CPI Inspection Report). Note the original image file is presented with a red arrow added at the location of the through wall leak.*

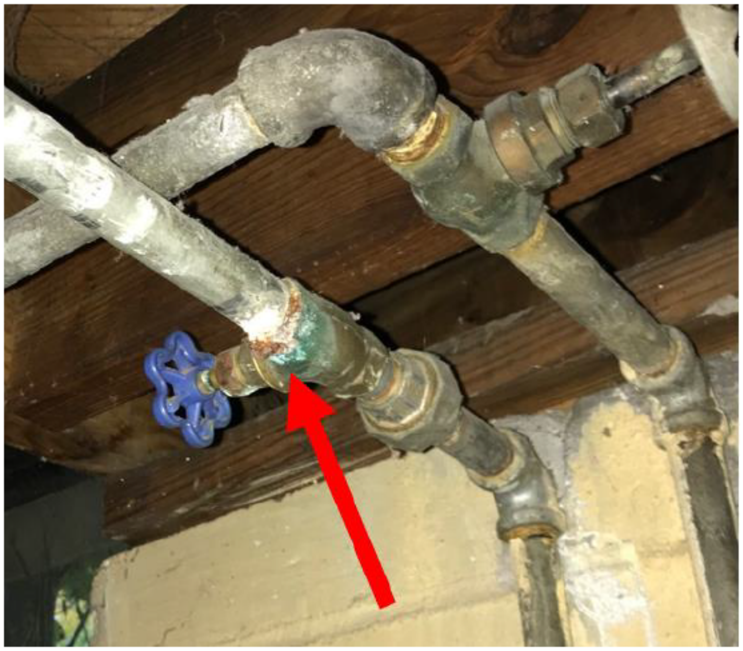


*Figure A6-3.4: Leaking drainline documented by Dr. Crowe. The leak is temporarily patched with the covering over the pipe when (Duquette Underlying Data, [redacted] CPI Inspection Report).*

As shown in Figure A6-3.4 above, even the drain lines are leaking in Flint homes due to corrosive water.

(3) Professor Duquette states:

*Without a single reference to actual observed damage to pipes or fixtures, Dr. Russell claims each and every pipe and other plumbing component within each of Flint's homes needs to be replaced (Duquette 2021, p. 7).*

My opinion that piping and plumbing throughout Flint were damaged by the corrosive Flint water is supported by an imposing collection of evidence, much of which I've already recounted. This evidence includes the Pieper et al. 2017 and 2018 data which included the August 2015 sampling; the photographs of premise plumbing produced by Professor Duquette; the fact that Flint River water was too corrosive for GM to use in their engine manufacturing facility; the high lead results from the copious sampling done during the Flint Water Crisis; and the photographs presented within this report (Figures A6-3.1) showing the intensity of the red water, indicating that corrosion was active and ongoing during the Crisis. Professor Duquette seemingly ignores every ounce of this evidence, and fails to offer a single piece of concrete evidence to support his contradictory conclusion that there was no damage.

Moreover, while there are fundamental issues with the Roy and Edwards 2020 sewage sludge paper (see Sewage Sludge Appendix), their data does indicate that substantial quantities of heavy metals, like lead and copper, were dissolved during the Flint Water Crisis. As an example, if the copper that was captured in the sewage sludge (3200 pounds during the Flint Water Crisis) were solely dissolved from copper pipes, then this amount of copper would have resulted in the total disintegration of 16,000 feet of pipe (over 3 miles of copper pipe during this 19-month period- see Sewage Sludge Appendix). Obviously, these levels of destruction were spread across the full spectrum of Flint homes with copper plumbing, suggesting that homes with copper pipe uniformly suffered corrosion and the loss of substantial pipe wall thickness during the Flint Water Crisis. This type of damage substantially reduces the useful life of the plumbing components and it can never be regained.

(4) Professor Duquette states the following regarding the protective pipe scales in Flint:

*Yet the scales that were observed are of the order of 350-400 μm in thickness. Russell's contention that the scale would have disappeared from the surfaces of the LSLs as a result of the switch is patently incorrect (Duquette 2021, p. 13).*

I made no such contention. I repeated what EPA's Mike Schock said in his deposition. In Mr. Schock's opinion, the high lead scales began to dissolve within a few days of the introduction of the corrosive Flint River water (recall that these types of scales would primarily be present in the 17 percent of homes that had LSLs). Whether it took a few days or a few months to dissolve the scales, it is clear that much of the scale did dissolve. Professor Duquette provides no reliable reference for his statement that the scales were consistently 350 to 400 microns thick (as a point of reference, a human hair is approximately 75 microns thick). And even if the scale were as thick as Professor Duquette claims, he has proposed that the scale had a thickness of

approximately 5 human hairs, which could not provide a long-term impenetrable barrier to the corrosive Flint River water.

It is well documented that several things began to happen when the switch to the Flint River water sources occurred in 2014. First, red water appeared immediately throughout the City, indicating that whatever protective phosphate scale had formed on the interior of the City's cast iron mains was rapidly dissolving and leaving the pipes' interior subject to corrosion. Second, the presence of lead in the drinking water indicated that these scales were no longer (if ever) sufficiently protective to stop the corrosion of even more lead from the LSLs. The presence of lead in the water in the homes also demonstrated the scales were incapable of protecting the high-lead brass and leaded solder from corroding, which is demonstrated by the fact that 85 percent of the homes that were sampled in August 2015 failing the EPA lead Action Level of 15 ppm (Pieper et al. 2018). As previously discussed, the photos from Professor Duquette's own home inspections provide proof that the scale was not sufficiently thick to prevent corrosion of the base metals, as there are numerous through-wall pipe pits.

# 4 Conclusions

As discussed throughout this Appendix, Professor Duquette presents a version of the events in Flint that is not based on the available data and observations. I have demonstrated that his opinions are wrong and undocumented. He speculates that the pipe scales prevented all corrosion, and that therefore there was no actual damage to the piping during the Flint Water Crisis. Professor Duquette also speculates that these same protective scales were the primary source of lead that was detected during the sampling rounds. Obviously, the same scale cannot be fully protective and also sufficient to be the cause of the high lead measurements during sampling. Although Professor Duquette claims that no damage occurred, he presents photos of leaking pipes as a part of his Expert Report, and still claims that no damage or leaks occurred as a result of the Flint Water Crisis.

Professor Duquette opines that high-lead brass and leaded solder were not significant contributors to the elevated lead concentrations in Flint. As demonstrated at length in this report, that opinion is simply not true: Only 17 percent of the Flint homes had lead service laterals (LSLs) as determined by the FAST LSL replacement program, and yet 85 percent of the homes that were sampled in August 2015 failed to meet the lead Action Level. It is impossible for the LSLs to be the primary cause of lead contamination problems in Flint if only 17 percent of the homes have LSLs, yet a majority (85 percent) of the homes demonstrated lead levels that failed the EPA Action Level. Professor Duquette does not support his opinions on this subject.

Finally, Professor Duquette generally fails to present any supportable rebuttal to my opinions. Professor Duquette similarly fails to rebut my opinions related to the system-wide impacts of the Flint Water Crisis, which distributed the same corrosive water to every home in Flint. Professor Duquette does not rebut the system-wide impacts of the Flint Water Crisis that I identified and that routinely occurred, nor does he rebut the attributes that make homes in Flint amenable to classwide consideration.

**Appendix 7**
**Analysis of Edwards's Sewage Sludge Data**

# 1 Summary

The Roy and Edwards (2020) and Roy, Tang, and Edwards (2019) papers attempt to utilize metals concentrations from the sewage sludge to understand corrosion in Flint and particularly water lead levels.[1] The sewage sludge is the solids that are separated from the sewage, and subsequently disposed of from the wastewater treatment plant (WWTP) (as opposed to the treated wastewater that is discharged to the Flint river). This sludge is tested monthly at the WWTP in Flint for metals, including copper and lead.

The authors of these papers developed a model in an attempt to use sewage sludge metals concentrations to estimate the concentrations of metals coming from the tap water in Flint. Unfortunately, the conceptual model employed by Roy and Edwards, and Roy, Tang, and Edwards is inherently flawed, thereby negating the usefulness of the model and the associated conclusions. The core flaw is that the model ignores the accumulation of these dense sludge containing metals in the sewer system, and the subsequent flushing of high concentrations of these sludges that occur when there is high sewer flow (i.e. during heavy rainfall). Additional flaws and challenges with this method are discussed at length in this Appendix.

As an example of this flawed conceptual model, the highest sewage sludge levels were documented in 2011, well before the Flint Water Crisis. The spring of 2011 was one of the wettest periods ever on record in Flint. The rain that entered the sewer system flushed the lead and additional solids to the treatment system. As the mathematical models utilized in these two papers fail to account for the flushing of lead and metals stored in the sewer system, the models are not useful for evaluating the real-time release of lead from the plumbing systems through the Flint tap water that goes down the drain. Any conclusions based on this model, such as those by the experts for the defense, share this similar flaw and, therefore, cannot be relied upon.

[1] Although this appendix is dedicated to explaining the flaws in Roy and Edwards' sewage sludge model, not all aspects of Roy and Edwards 2020 are problematic. For example, Roy and Edwards' sewage sludge analysis has no bearing on the paper's findings regarding *Resident X*, to whom I frequently refer throughout my rebuttal report.

# 2 Overview

Sewage sludge is the solids that are settled and removed (sludge) from the sewage at the WWTP (as opposed to the treated water that is discharged to the Flint river). In the two Edwards papers, measurements from the Flint sewage sludge were utilized in an attempt to better summarize what occurred in Flint with respect to the Flint Water Crisis and to attempt to model the Water Lead Levels (WLL). These papers utilize this data along with the reported digested sewage sludge mass generated each month for input into a regression model to attempt to model WLLs.

The sewage sludge is collected, concentrated, digested, dried, and then disposed of either by incineration or in a landfill. Flint utilizes an anerobic sewage sludge digestor and a filter press to reduce the volumes of sludge generated for disposal. Once a month the Flint WWTP measures heavy metals, including copper and lead, in the processed sewage sludge.

Measurements of certain chemicals or constituents at the WWTP can, at times, yield useful information, as the WWTP receives an integrated flow of everything discharged throughout the City. Unfortunately, the movement of lead in this system does not present a simple transport process, which can be easily analyzed based using the sewage sludge mass and heavy metal concentration. To expand on that issue, lead is released and transported from premise piping systems, travels down the drain to the sewer, and then goes to its ultimate fate, which either is that it can be discharged with the water from the WWTP into the Flint river or collected in the digested sewage sludge. This transport process is extremely complex and does not lend itself to the straightforward analysis used by Roy and Edwards.

Accordingly, it is our position that the analysis in both papers is fundamentally flawed. This flaw emanates primarily from the fact that there is not a 1:1 relationship between lead released to the sewers and lead entering the WWTP. This flaw is caused by significant and indeterminable time delays during lead transport in the sewer system to the WWTP. The depth of analysis provided by Roy and Edwards is insufficient to properly characterize either the situation at Flint or to address the actual conditions at Flint with respect to the fate and transport of lead in the Flint sewer system and, therefore, the source of this lead being directly measurable in the WLLs during the Flint Water Crisis (as required in the Roy and Edwards model).

The core flaw is that the model ignores the accumulation of these dense metals, such as lead, in the sewer system, and the subsequent flushing of high concentrations that occur when there is high flow (i.e. during heavy rainfall). The density of lead causes it to settle at low points throughout the sewer collection system. Under high flow events, such as heavy rainfall, this lead that has accumulated in the bottom of the sewer and collection system is flushed out. As a result, during these high flow events, lead that has been stored up in the sewer over an extended time period is flushed into the WWTP. As we demonstrate below, the lead concentrations in the biosolids are significantly correlated with the monthly rainfall and the monthly total flow processed at the WWTP. Therefore, any modeling efforts which ignore this impact, such as those of Roy and Edwards, are inherently flawed and will lead to erroneous conclusions about the real-time water lead levels (WLLs) in the Flint drinking water.

**Appendix 7**

**Analysis of Edwards's Sewage Sludge Data**

As an example of this flawed conceptual model, the highest sewage sludge levels presented in the Roy and Edwards paper were documented in 2011, well before the Flint Water Crisis. The spring of 2011 was one of the wettest periods ever on record in Flint. The rain that entered the sewer system flushed the lead and additional solids to the WWTP. As the mathematical models utilized in these two papers fails to account for the flushing of lead and metals stored in the sewer system, the models are not useful for evaluating the real-time release of lead from the premise plumbing systems. Any conclusions based on this model, such as those by the experts for the defense, share this similar flaw and cannot be relied upon.

The defense experts Professors Gagnon and Duquette, and Dr. Finley (a health expert whom I was not asked to focus on), all relied upon the modeling results from these Edwards papers to support their conclusions about the impact of this lead on Water Lead Levels. Professor Duquette even used the Edwards data to try to suggest that that the Flint Water Crisis didn't happen in 2014, as there was a previous spike in lead in 2011. The Defense experts incorrectly assert this, because of the high sewage sludge lead levels, such as those measured during 2011 (the heaviest rainfall on record in Flint).

As discussed further below, the Roy and Edwards model does not provide a meaningful or predictive estimate of water lead levels, particularly during the high flow/wet weather events. As a result, the conclusions of Professors Gagnon and Duquette that are based on the Roy and Edwards predicted Water Lead Level WLLs are fundamentally flawed and wrong.

There are additional issues with the sewage sludge analysis that are discussed below. These issues call into question the reliability of the model's predictions and demonstrates that the Edwards model which is based on the sewage sludge data cannot be used to predict WLLs in Flint.

# 3 High Infiltration and Inflow in the Sewers in Flint

The sewers in Flint were originally installed as a combined sewer system. A combined sewer system utilizes a single pipe to collect both sewage and stormwater. Based on a discussion with WWTP staff, an attempt was made by Flint in the early 1900s to separate the sewers. This separation process would require the rerouting of every non-sewage source of water to a new storm-sewer. Unfortunately, this process is involved, costly, and nearly impossible to do after the fact. The sewer flows in Flint speak to the reality of this: there is significantly more flow in the sewer system when it rains—so much so that at times the Flint WWTP has to discharge partially treated wastewater directly into the Flint River, because it does not have the capacity to handle the additional storm water flows. These undesired inflows of storm water and drainage into the sewer system are commonly known as *Infiltration and Inflow* (I&I).

The 2019 Roy, Tang, and Edwards paper briefly discussed this issue. However, their assessment indicates that their efforts are based on a flawed conceptual model:

*In terms of possible confounding factors, the stormwater in Flint is not discharged to sewers, reducing the likelihood that surface water runoff or hydrant flushing of water would influence the results*.

Their statement is inaccurate. The City personnel reported that storm sewers were installed in Flint decades ago in an attempt to separate the combined sewer system. However, the City personnel informed us that the sewers transport a mix between the sanitary sewer and the storm water. The flow data at the WWTP corroborates that this decades-old effort was a failure, as the sewage flow peaks dramatically during rain events. Indeed, Flint was the number one Combined Sewer Overflow (CSO) discharger in the State of Michigan in 2013.

When high flow occurs in the sewer, the energy of the flowing water causes substantial increases in the transport rate of solids through the sewer system. As I testified during my deposition in this matter, following the seminal work of H.A. Einstein Jr., the transport of sediment is related to the cube of the velocity (Einstein, 1950). Thus, extreme rainfall and the associated flows in the sewers cause the transport of dense lead containing solids within the sewers. The result is that there is a substantial accumulation of lead in the sewage sludge at the WWTP during and following these events. It is this flow driven intensification, as was observed during the spring of 2011 (one of the wettest periods ever observed in Flint, MI), that caused the spike in the lead content of the sewage sludge, and not some issue with increased water lead levels, as was proposed by Roy and Edwards and mimicked by Professors Gagnon and Duquette and Dr. Finley.

Thus, the dense lead solids lay in the sewer and slowly move along through the sewer over months or years waiting for a peak rainfall/flow event to occur. Then those solids are flushed through the sewer system into the treatment plant (and into the digested sewage sludge) or settled out (hopefully) when that peak flow occurs during heavy rainfall. The lead is then either discharged during a CSO event from Outfall 003 or incorporated into the sewage sludge. The result is that there was a spike in lead that was pushed into the treatment plant and then

accumulated with the total sludge mass during these high rainfall events. This scenario is exactly what occurred in the spring of 2011, when there was both a dramatic increase in sludge lead concentration and sludge mass.

In the Roy/Edwards 2019 paper, they partially addressed the events that occurred in April of 2011. In that month, they noted the following regarding Detroit in the spring of 2011:

*We speculate that this anomaly may have somehow been linked to treatment upsets or other events during record Detroit rainfall, which was national news in that exact time period (Bienkowski, 2013).*

The anomaly that they are speaking of is the spike in lead mass they observed in the digested sewage sludge in April 2011. This lead spike was due neither to a treatment plant upset at DWSD (water) nor an upset at the City of Flint WWTP. It was solely due to the flushing of the sewers that occurred during this excessive period of excessive rainfall and I&I in Flint (the same intense rainfall they referenced above that occurred in Detroit, which is Flint's neighbor).

# 4 Understanding Digested Sewage Sludge and Lead Transport

On first glance, the lead concentrations in digested sewage sludge seem like they could provide useful information and insight into the Flint Water Crisis. However, the dynamics of the lead release, and its potential capture in the WWTP digested sewage sludge are complex. These complex dynamics do not lend themselves to providing the insight required to make such a model either simple or useful. Stated differently, the model developed by the Edwards Team is insufficiently complex to address the fundamental issues needed to model lead transport in the Flint sewer system and into the WWTP.

Modeling the lead transport in the sewers is further complicated by the dynamics regarding the particulate and dissolved lead, which are transported to the WWTP, and how long that lead remains in various locations within the WWTP and sewage collection system (lead residence time). Lead can be temporarily captured both in the sewer and at the WWTP, only to make its way into the sewage sludge at a later time. As a result, the simple model and data utilized by the Edwards Team falls subject to the familiar phrase about computer modeling – garbage in, garbage out.

Even the single monthly sample that is collected of the lead data in the sewage sludge presents a substantial barrier to detailed analysis. The digested sewage sludge is not well homogenized (mixed), which further complicates representative sampling for metals, especially particulate metals (even more so when only a single monthly sample is analyzed). The Flint WWTP generates an average of 170 metric tons of sludge (dry weight) a month. However, the sludge contains approximately 3 parts of water for every part of dry sludge mass. Therefore, the average bulk sludge mass ranges from 600-700 metric tons per month, and a sample of the sludge has a mass of perhaps 100 grams (therefore, the monthly sample is 0.000006 percent of the monthly sludge produced making it hard for any routine sample to be truly representative). This low frequency of data collection, which is measured on a non-representative single sample, further limits the usefulness of this sewage sludge lead data.

Lead in the Flint sewers was generated as two different types, particulate and dissolved. The particulate lead includes larger heavy pieces, such as, the lead-laden scale, as opposed to the minute dissolved (or colloidal) lead. The efficacy of capture of the particulate lead (percentage retained) is unknown (almost assuredly it is not the 85 percent that Edwards testified to), and it may or may not be well captured at the Flint WWTP. The dissolved or colloidal lead is unlikely to be captured at the WWTP, and will not be accounted for in the sewage sludge data. When the WWTP has an overflow of partially treated sewage to the Flint River, it is likely that this lead is discharged to the environment, and not captured by the sewage sludge data and consequently not accounted for in the model.

To further understand the complexities of lead transport in Flint, I looked for correlations between various factors and the lead concentrations in the digested sewage sludge. These are factors that were not included in the analyses performed by the Edwards Team. This analysis included data from the Monthly Operation Reports (MOR) produced by Flint, and rainfall data in

Flint, MI obtained from NOAA. These MORs contain the same data utilized by the Edwards Team, namely lead concentration and mass of sludge produced monthly. We combined this information with additional factors including: monthly wastewater flow, monthly rainfall, maximum daily rainfall observed during a given month. A summary of the results from this analysis and the correlation is presented in Table A7-7.1.A.

The results of this analysis demonstrate that critical factors, not related to the lead levels in the drinking water (the basis of the Edwards's model), play determinant roles in controlling the lead observed in the sewage sludge at the WWTP. Said another way, the sewage sludge lead concentrations are not a reliable tool to model the lead concentrations in the potable water (WLL). Both Professors Gagnon and Duquette and Dr. Finley incorrectly based some of their opinions on this flawed model.

We found that the lead concentrations in the WWTP digested sewage sludge were directly correlated with the rainfall (both monthly total and maximum monthly daily rainfall observed), and monthly wastewater treatment flows. This finding indicates that the dense lead particulates settle in the sewer and are then flushed out at a later time during high flow rain events. Therefore, the measured concentrations at the Flint WWTP are not representative of the real-time lead released from the Flint plumbing systems, and the Roy and Edwards model is, therefore, inherently incorrect. The monthly sewage sludge lead concentrations and quantity are tied directly to the rainfall that occurs.

I similarly observed a significant positive correlation between the mass of digested sewage sludge produced each month and rainfall (indicating cause and effect). This finding is critical as it has substantial influence on the analysis that Edwards's team performed. Specifically, they calculated the monthly generation of lead by multiplying the sewage sludge mass by the measured lead concentration in the sewage sludge. Both of these factors increased when there is more rainfall, essentially multiplying the effect and decoupling it from the real-time lead release from the drinking water (WLL).

This reality is highlighted by the lead digested sewage sludge data collected in 2011. The spring of 2011 was the wettest spring on record in Flint, with over 17 inches of rainfall (the previous historical record was 13.8 inches). This spring was described well by the title of a Michigan Live article (May 19, 2011): *National Weather Service: Flint has had the wettest spring in history*.

Figure A7-4.1 below shows a comparison of the sewage sludge lead concentrations with the monthly rainfall totals in 2011. As can been seen in the figure, there is a correlated trend between rainfall and lead concentration in the digested sewage sludge (offset as described in the Addendum). Figure A7-4.2 below shows the monthly digested sewage sludge mass generated vs. monthly rainfall in 2011. Rainfall was found to be significantly positively correlated with both parameters. By comparing these two graphs, it can be seen that the lead detention time within the WWTP is substantially longer than the average sludge detention time. This phenomenon can be seen from the tail of the curve starting around June and running into December, and this phenomenon is the reason that the tail of the curve appears to be less correlated than the first six months of 2011.

**Appendix 7**

**Analysis of Edwards's Sewage Sludge Data**

What is seen therein is that the average detention time of the lead in the sewage sludge is longer than the sewage solids. The high spring (2011) rainfall flushes the sewage sludge and the lead solids into the WWTP, where the heavy lead containing sewage sludge is retained within the digesters and tank bottoms for a longer time. Ultimately it is diluted out with new sewage solids and the system comes into equilibrium, and the sewage lead mass decreases until the rainfall and sludge data more closely aligns. Clearly, the transport of lead in the sewage sludge is a highly variable phenomenon that does not lend itself well to predicting WLL in the City of Flint.

**Figure A7-4.1: Lead concentrations in digested sewage sludge (left axis) vs monthly rainfall (right axis). Note the general similar trends of the two lines, particularly during months with high rainfall (March, April, May and July).**

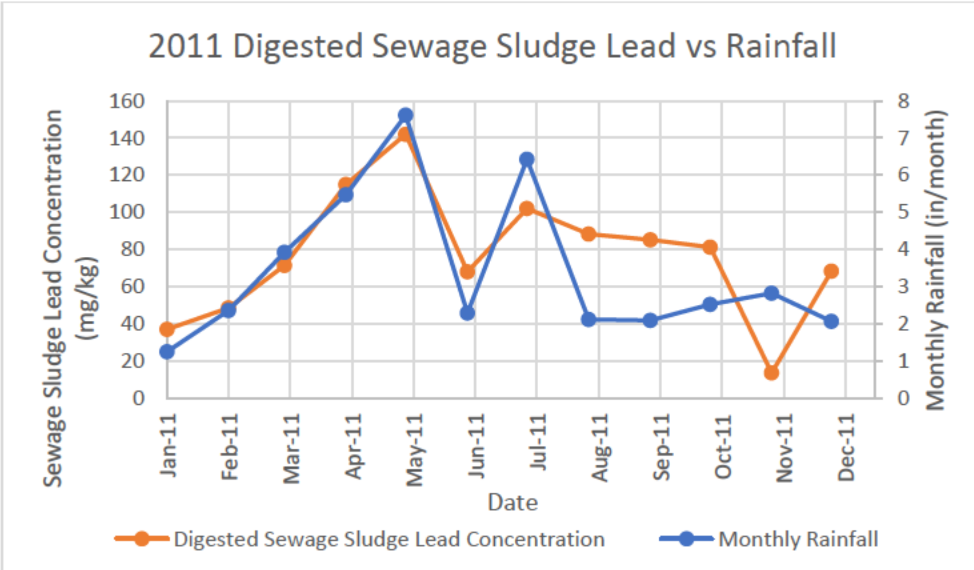
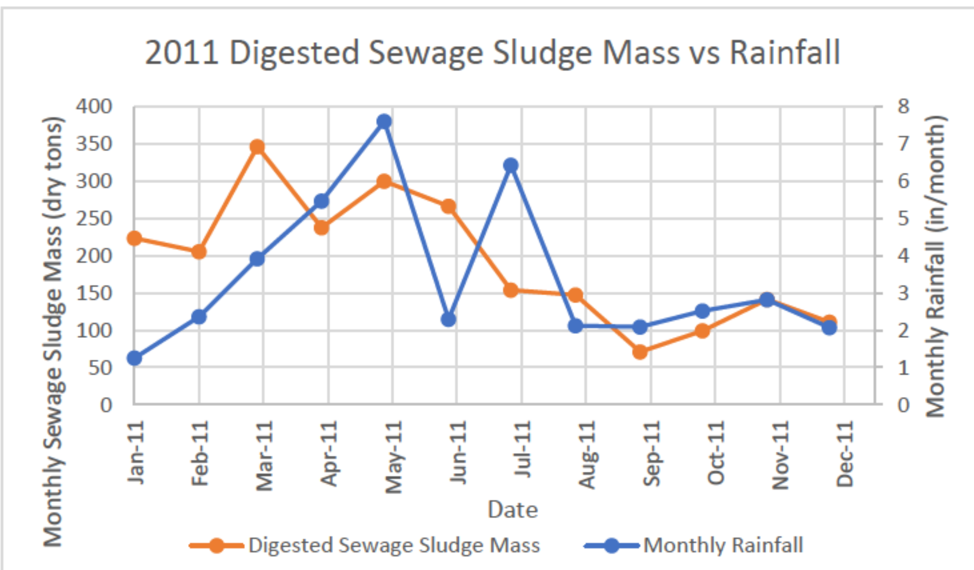



**Figure A7-4.2: 2011 Monthly digested sewage sludge mass (left axis) vs monthly rainfall (right axis).**




Together, these findings highlight the difficulty of using sewage sludge data for to model the estimate lead levels in the drinking water (WLL).

Based on these findings, it is my opinion that the work done by Roy and Edwards 2020 and Roy, Tang, and Edwards 2019, cannot be used as a tool to understand the Flint Water Crisis WLLs and its aftermath. Further, the modeling efforts by Edwards's team have no relevance to the

spikes they predicted in the WLLs based on the digested sewage sludge lead concentration during 2011.

# 5 The Source of the Lead and Copper in the Sludge During the Flint Water Crisis

None the less, the digested sewage sludge data may still be useful outside of the 2011 period with the caveats noted above. The digested sewage sludge data presents interesting insights into the problems with lead in Flint. During the Flint Water Crisis (May 2014-October 2015), the digested sewage sludge data suggests that approximately 190 kg of lead were captured at the WWTP. While the precise time period that this lead was generated cannot be ascertained, there are important facts that can be ascertained: most of the lead and copper in the sewage sludge (except for any generated by industrial activities) came from either a reduction in wall thickness of the lead service lines and/or the high-lead containing brass fixtures and solder. During the Flint Water Crisis, it has been documented that there were increased Water Lead Levels (WLL) that resulted from the corrosive Flint River water being distributed within all homes and businesses in Flint. Although the sewage sludge data does not allow us to know when exactly this lead was released, it does show that there is a substantial amount of lead that arrived and was captured at the WWTP during the Flint Water Crisis. This doesn't account for the additional lead which was discharged into the Flint River with the treated wastewater, or delayed in transport to the WWTP.

A similar assessment was performed for copper and indicated that approximately 1450 kg/ ~3200lbs were captured in the WWTP sludge during the Flint Water Crisis (May 2014-October 2015). Although detailing the transport processes for copper in the sewer system are beyond the scope of this Appendix, the results suggest that a substantial amount of copper was released during the Flint Water Crisis. This finding supports that dissolution of scales and/or active copper corrosion were occurring (as described in the Russell 2020 report).

To put this mass of copper in relatable terms, if all of this copper is solely from corrosion of copper pipe, this mass of copper corresponds to totally dissolving 16,000 ft of ½ inch copper (type M) tubing. Obviously, the pipes were not completed dissolved, and instead, this damage was spread throughout all the homes and businesses utilizing copper piping in Flint. Thus, each of the homes with copper piping would have suffered significant pipe-wall thickness loss from this level of corrosion during the Flint Water Crisis. Again, while these dynamics are complicated and not captured in this simple analysis, this observation supports the finding that significant copper corrosion occurred during the Flint Water Crisis.

With the exception of any industrial sources, all of the heavy metals captured in the sewer discharge and in the digested sewage sludge at the Flint wastewater plant came directly from the pipe walls and solder of the residential and commercial plumbing systems in Flint. As discussed with the WWTP staff, industrial sources of lead have substantially reduced due to decreased industry in Flint. For a point of reference, 95 percent of Flint's wastewater originates from domestic sources, indicating a miniscule amount of industrial sources.

# 6 Addendum:

## 6.1 Data and Statistical Analysis of Digested Sewage Sludge Data

Monthly digested sewage sludge (mass and lead concentrations) and monthly wastewater flow were obtained from Monthly Operating Reports (MORs) from the Flint WWTP. Rainfall data, monthly total and daily max each month were obtained from NOAA. The digested sewage sludge, wastewater flows, and rain data were analyzed in IMB's SPSS software to determine significant correlations. The variables were tested for normality utilizing a Shapiro-Wilk test and were determined to not meet a normal distribution. Therefore, non-parametric correlation tests were utilized, specifically a two tailed Spearman Correlation. Correlations were determined to be statistically significant at the 0.05 level. The sewage sludge lead concentrations were offset by one month due to when the samples are collected each (typically the start of a given month) and the residence time of the sludge in the WWTP (following Roy et. al 2019). The results of the correlation analysis are shown in Table A7-7.1.A below.

*Table A7-7.1.A: Spearman correlation coefficients for the parameters analyzed. Bold text with an "*" indicates that the correlation is statistically significant at the 0.05 level. A positive correlation coefficient indicates that the values are positively correlated (i.e. when one increases, the other does as well) and a negative correlation coefficient indicates a negative correlation (i.e. when one increases the other decreases).*

| | Monthly Sludge Tons (Dry) | Monthly Rainfall Total | Maximum Rainfall Day in Month | Monthly WWTP Flows | Digested Sewage Sludge Lead Concentration |
|---|---|---|---|---|---|
| Monthly Sludge Tons (Dry) | | **0.22*** | **0.23*** | **0.31*** | -0.04 |
| Monthly Rainfall Total | **0.22*** | | **0.87*** | **0.23*** | **0.21*** |
| Maximum Rainfall Day in Month | **0.23*** | **0.87*** | | 0.17 | **0.21*** |
| Monthly WWTP Flows | **0.31*** | **0.23*** | 0.17 | | **0.22*** |
| Digested Sewage Sludge Lead Concentration | -0.04 | **0.21*** | **0.21*** | **0.22*** | |

A total of 107 months of data were utilized in the analysis. One month was removed to account for the offset in the lead data.